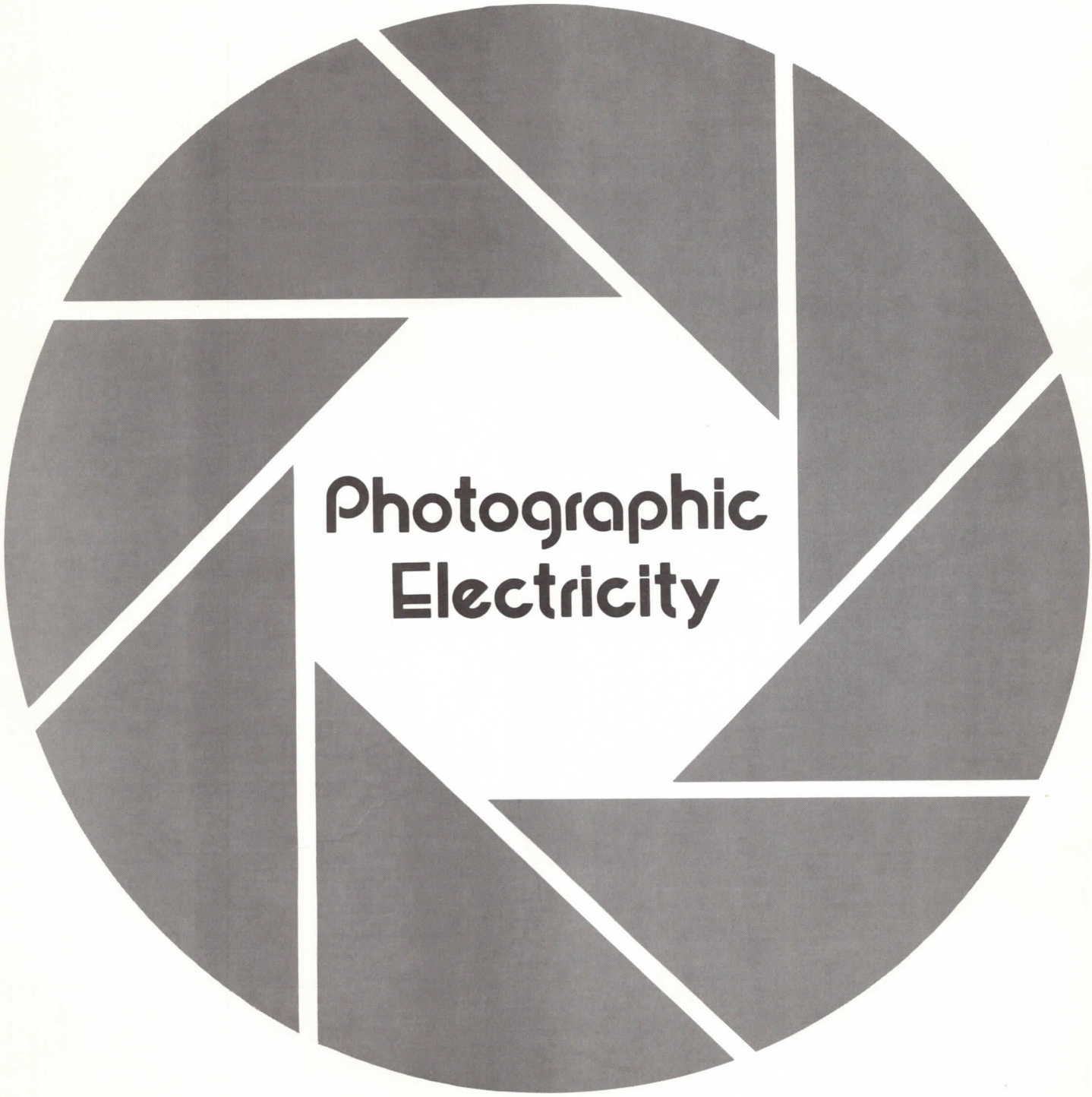
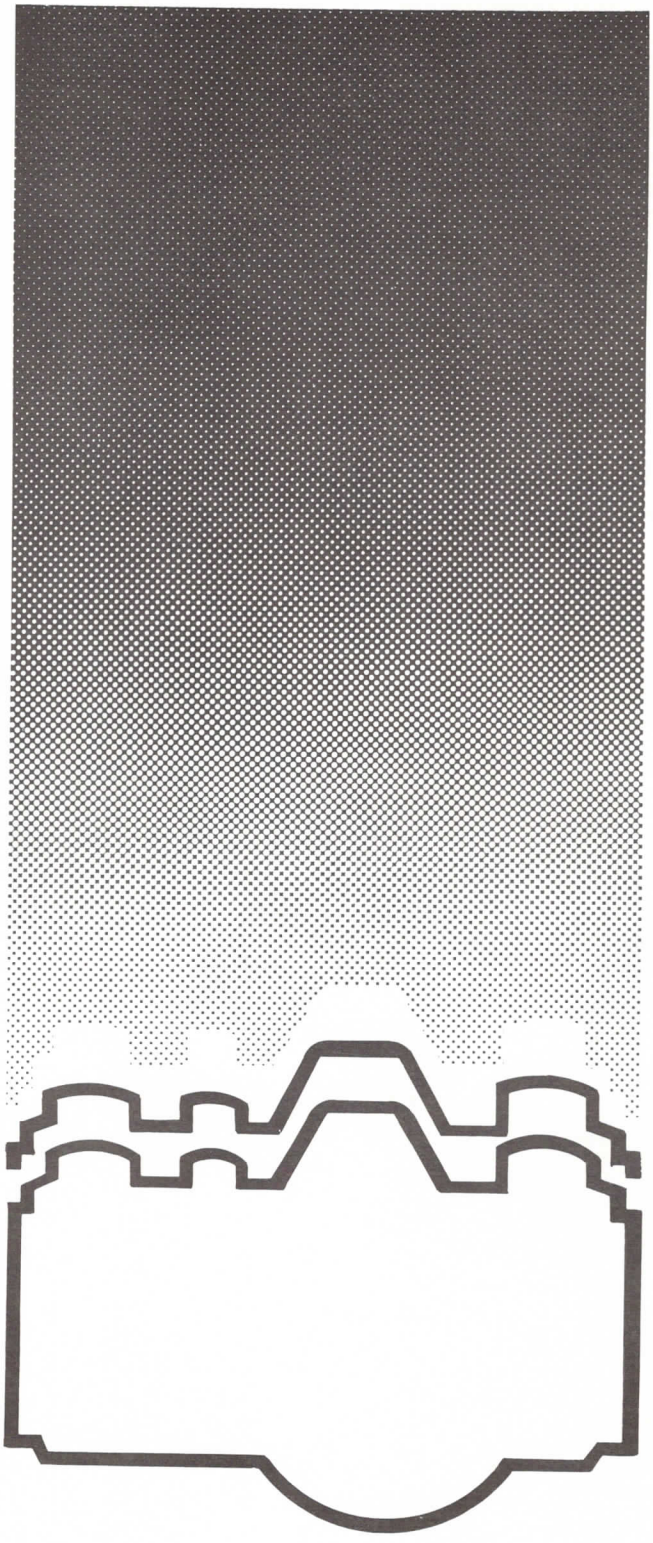

Photographic
Electricity



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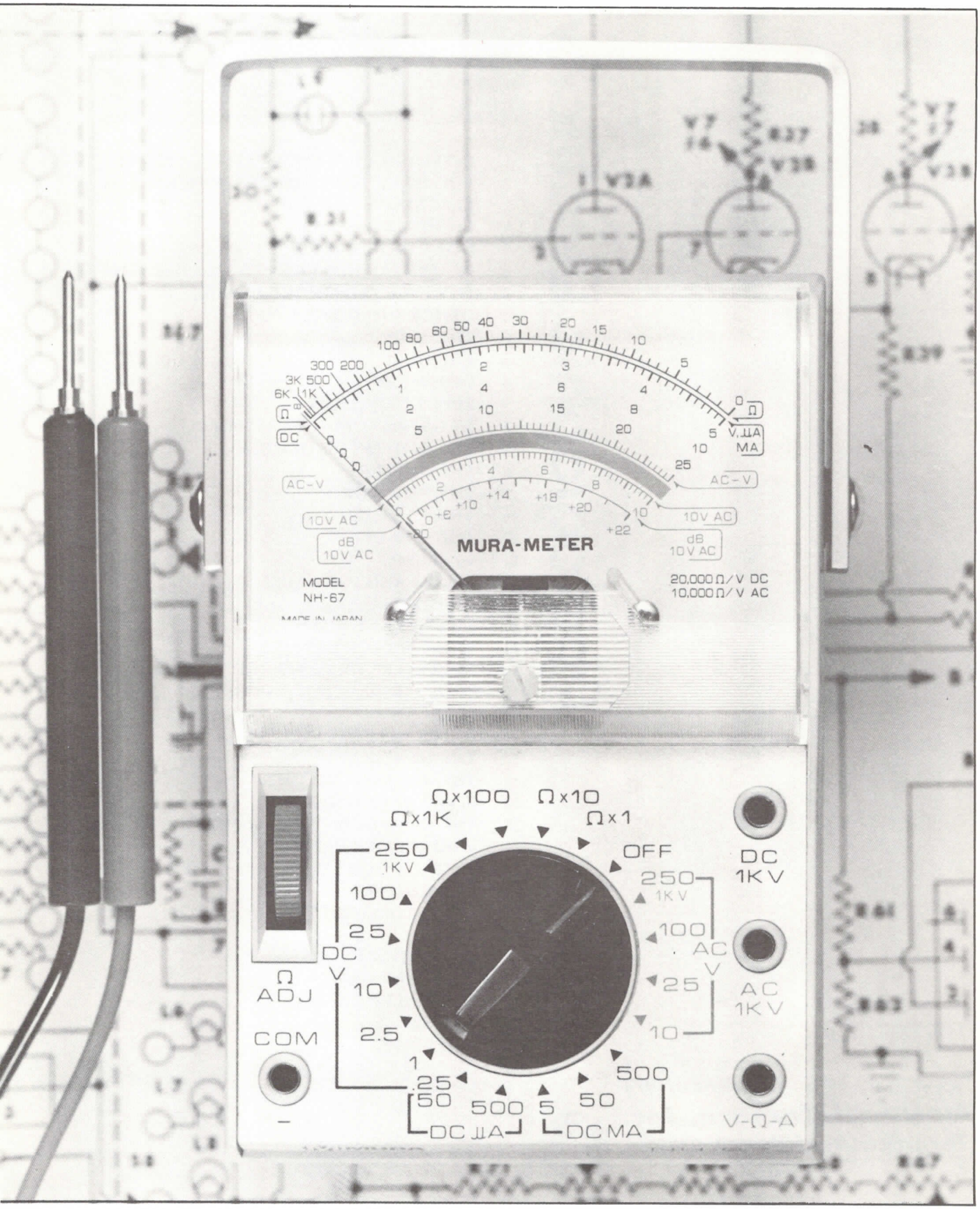
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MURA-METER
MODEL
NH-67
20,000 Ω/V DC
10,000 Ω/V AC
Ω ADJ
COM
DC 1KV
AC 1KV
V-Ω-A
OFF
DC V
AC V
DC μA
DC MA

INTRODUCING ELECTRONICS

For many years, amateur cameras were nothing more than simple mechanical devices used to take snapshots. Many cameras had fixed shutter speeds and lens openings. In the early days of photography, the photographer with an adjustable camera relied upon tables and charts to determine exposure. Often consulting his tables and making calculations, the photographer had to make a guess at his final exposure.

Not long after photography got its start, the first light meters began to appear. The light meter was an effort to remove



FIGURE 1

some of the guesswork from photography. The earliest light meters used optical principles. By the late 1930's, photoelectric light meters became available. The first photoelectric meters were self-contained and required no batteries. By the 1950's, battery operated cadmium-sulfide cell meters were beginning to appear. In 1963, the first electronically controlled shutter was marketed (in a Polaroid Land camera).

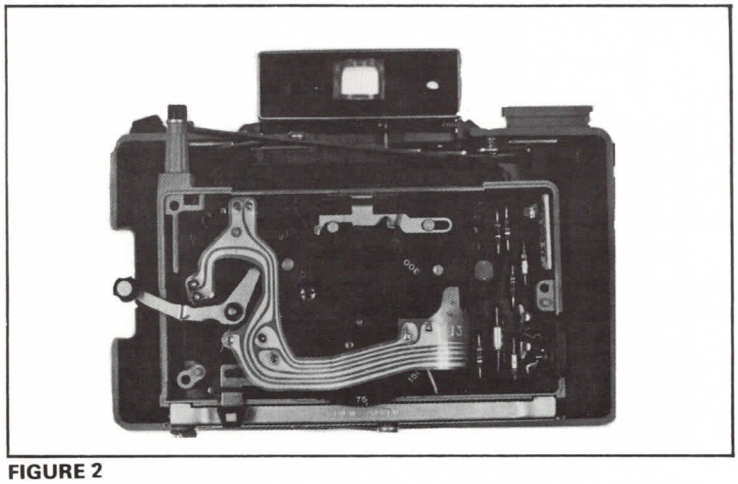


FIGURE 2

Today's camera is much different from early nonadjustable models. Today's camera may have, in addition to a compact built-in light meter, sophisticated circuitry which almost makes the photographer obsolete. In order to service modern cameras, the photo equipment technician must understand both the mechanics and the electronics of the camera he is called upon to repair. This text and the texts covering exposure meters, electronics, and sound systems should help to give you the edge over the technician who is not trained in photographic electronics.



FIGURE 3

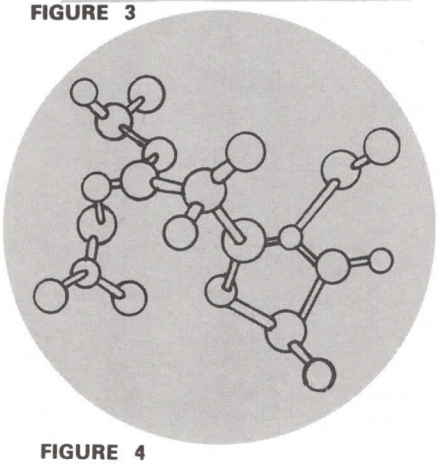


FIGURE 4

YOU HAVE TO START SOMEWHERE

You may have met repair people who do not understand the work they do. If a problem occurs that is not covered in their repair manual, they are stumped. So, although you could repair some electric circuits without an understanding of electricity, you'll be far ahead of the average technician if you have a background that lets you dig deeper—to see the roots of the problem.

Understanding circuits is easier if you understand the fundamentals of electricity.

All matter, liquid, solid and gas, is constructed around a fundamental building block—the atom. The atom in its pure form such as hydrogen, helium, oxygen, carbon or iron is called an **element.** In combination, atoms of the various elements form **molecules.** A molecule may be one or more atoms of the same element or combinations of different elements. For example, steel is based on the elements iron and carbon. If any form of matter is divided again and again, at some point one more division will result in that matter losing its characteristics which allows us to give it a name. In the case of a compound containing more than one element, this will be when the different atoms are separated.

ELECTRONS

When one atom of an element is reached, an additional division will separate the atom into its component parts. Each atom consists of a heavy center section called a **nucleus** surrounded by much lighter orbiting **electrons.** It's the orbiting electrons that are necessary in order to have an electric current.

The orbiting electrons surround the atom's nucleus in **shells.** Electrons are held in orbit around the nucleus by an electric force due to the electron having a negative charge and the nucleus having a positive charge. **These opposite charges attract each other.** The electrons are prevented from banging into each other because **their like charges cause them to repel each other.**

Each electron shell or electron orbit can hold only a certain number of electrons. In our diagram, the first two shells of an atom are shown. The inner-most shell can hold no more than two electrons. The next shell can hold up to eight electrons. In every atom, the shells fill up with electrons from the innermost shell outward. Each inner shell must be complete before the next shell begins to fill with electrons.

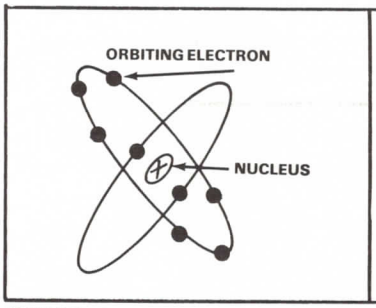


FIGURE 5

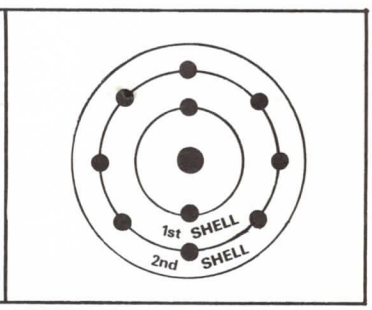


FIGURE 6

CONDUCTORS

The outer shell will not always fill completely. The outer shell may contain its full number of electrons, or from one fewer than its full number of electrons to only one electron. Atoms with only one electron in their outer shell make the best conductors. This is because electricity is electron motion and the single outer shell electron is almost completely free to move.

It's just a little more complicated, though. In order to use electricity, electrons must flow from one spot to another. In a good conductor such as copper wire, the wire is made up of a framework of copper atoms. Each atom is close to its neighbor. Because the atoms are close together and each atom has only one loosely bound electron in its outer shell, the outer electron is free to move to the outer shell of its neighbor copper atom. Because these electrons are free to wander, they are called **free electrons.**

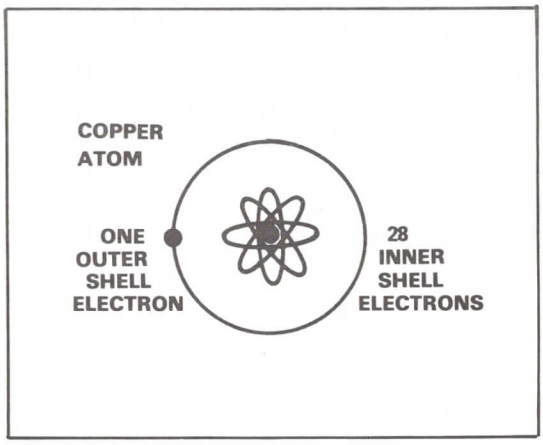


FIGURE 7

If you could stand back for an imaginary distant look at the copper wire, you would see a framework of copper atoms with a cloud of free electrons drifting between atoms. Because copper has a large number of free electrons, it is a good conductor of electricity. The more free electrons a material has in a unit of its volume, the better conductor of electricity it is. All metals have a large number of free electrons, though the number of free electrons in one unit of volume varies, and so some metals are much better conductors of electricity than others. Here is a partial list of conductors of electricity arranged in order from the best conductor to worst conductor.

Silver
Copper
Gold
Aluminum
Iron
Lead
Mercury
Carbon

Notice that copper, one of the most often used conductors, is not the best conductor. Copper is used as the conductor in most electrical circuits because it's far less costly than the only better conductor, silver.

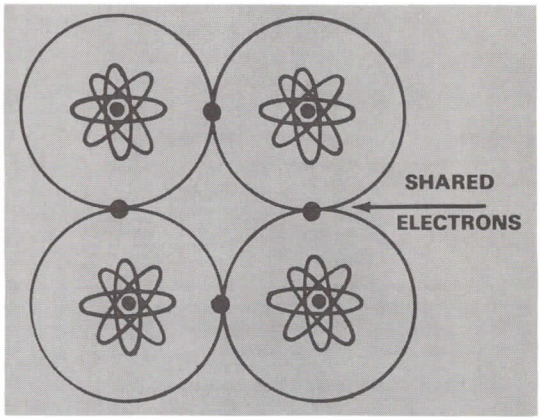


FIGURE 8

INSULATORS

Other materials that contain far fewer free electrons than metals are called **insulators.** The best electric insulators are materials where the atoms are linked so that any electrons in an incomplete outer shell are shared by several atoms in the compound and so locked in place. A material that binds the outer shell's electrons like this is called a **polymer.** Common polymers are materials like oil, plastic, paper and mica.

Because it is impossible to make a pure polymer, all polymers to a certain degree are conductors. Also, impurities such as water can build up in a insulator tending to reduce the insulating ability of the polymer.

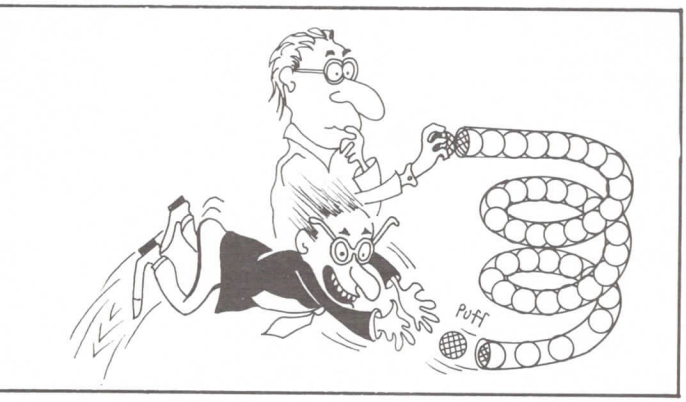


FIGURE 9

CONDUCTORS

A wire made of a good conductor is like a pipe for electrons. In order to make the electron pipe easier to understand, imagine for a moment a large copper pipe full of golf balls. The golf balls are packed into the pipe, each one touching the other. However, since no force is being applied to the golf balls they don't go anywhere. If someone adds a golf ball at one end of the pipe, immediately a different ball pops out the other end.

A copper wire handles electrons in much the same way. If an electron is added to the electron cloud at one end, another electron is pushed out the other end. In order to make a copper wire or electron pipe work, some device which will push electrons in one end of the pipe and receive electrons from the other end of the pipe is needed.

TEST YOURSELF QUIZ #1

1. All matter is constructed around the ATOM which is the fundamental building block of all matter.
2. The atom is made of a heavy center section called the NUCLEUS surrounded by orbiting ELECTRONS.
3. Good conductors are made of atoms having FREE ELECTRONS in their outer shells.
4. Materials with few free electrons are called INSULATORS OR POLYMERS

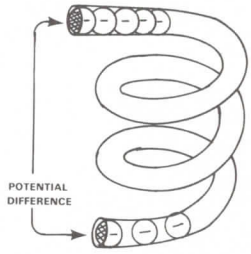


FIGURE 10

POTENTIAL DIFFERENCE AND THE VOLT

Adding electrons to one end of the wire and removing them from the other is easy if we make a device which will create a **potential difference.** A potential difference (PD) exists when a conductor has more electrons at one end than the other. A potential difference may be created one of three ways: by adding electrons to one end of a conductor, by removing electrons from one end of a conductor, or by adding electrons at one end of a conductor and removing electrons from the other end of the conductor.



FIGURE 11

THE ELECTROCHEMICAL CELL

A common way of obtaining a potential difference in photographic applications is the electro-chemical cell or battery. Strictly speaking, a battery is a combination of individual cells. However, the meaning of battery has been blurred through usage, so in non-formal use "battery" is often used interchangeably with "cell."

The cell is a device made up of two conductors called **electrodes** and a chemical called an **electrolyte** which converts chemical energy into electric energy. In operation, due to chemical action, one electrode builds up a surplus of electrons and the other electrode develops a deficiency of electrons. The battery terminal with an excess of electrons is the **negative terminal.** The battery terminal deficient in electrons is the **positive terminal.**

When the cell's electrodes are connected to a conductor, the electrode with an excess of electrons pushes electrons into one

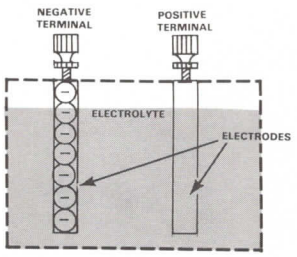


FIGURE 12

end of the conductor. The electrode deficient in electrons receives the electrons pushed out the other end of the conductor.

OTHER SOURCES OF PD

Other common ways a potential difference is developed for use in photographic equipment are through photocells in which light energy is converted to electric energy and piezoelectric crystals in which pressure or stress is converted to electric energy. Any time a potential difference is created the force which moves the electrons, called **electromotive force,** occurs. Electromotive force is most often seen in its abbreviated form EMF. Electromotive force and potential difference are measured in **volts.**

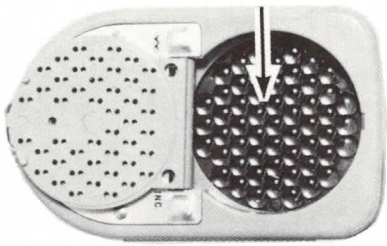


FIGURE 13 The selenium cell used to operate an exposure meter.

THE AMP

Because of the large numbers of electrons in motion in even the smallest circuit, a measuring system which allows large numbers of electrons to be represented by much smaller units has been developed. An **ampere,** often abbreviated amp, is the standard unit of electron flow. One amp represents just under six and one quarter quintillion electrons passing one point in a circuit in one second.

In summary: Potential difference and EMF are often interchanged. Both are measured in volts and are commonly called voltages. Voltage is the pressure on electrons which causes current. Current is electrons being moved.

ONE AMPERE =
6,240,000,000,
000,000,000
ELECTRONS

FIGURE 14

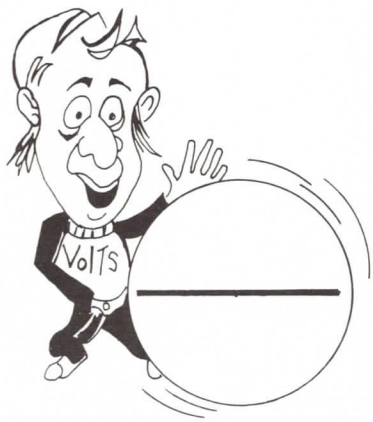


FIGURE 15

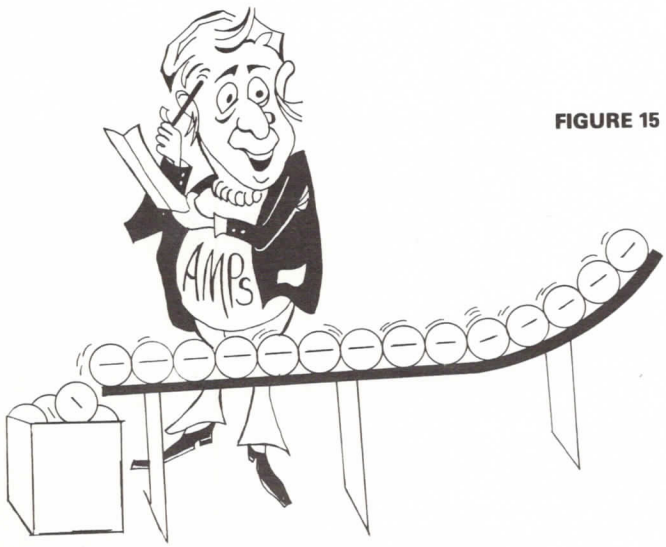


FIGURE 16

THE OHM

Just as there is opposition to work being done in the mechanical world, there is opposition to work being done in the electrical world. When an electric current is used to do work, the circuit resists the flow of electrons. Opposition to the flow of electrons is called **resistance.** The unit for resistance is an **ohm.** One ohm of resistance is produced by a circuit with one amp of current flowing due to a pressure of one volt.

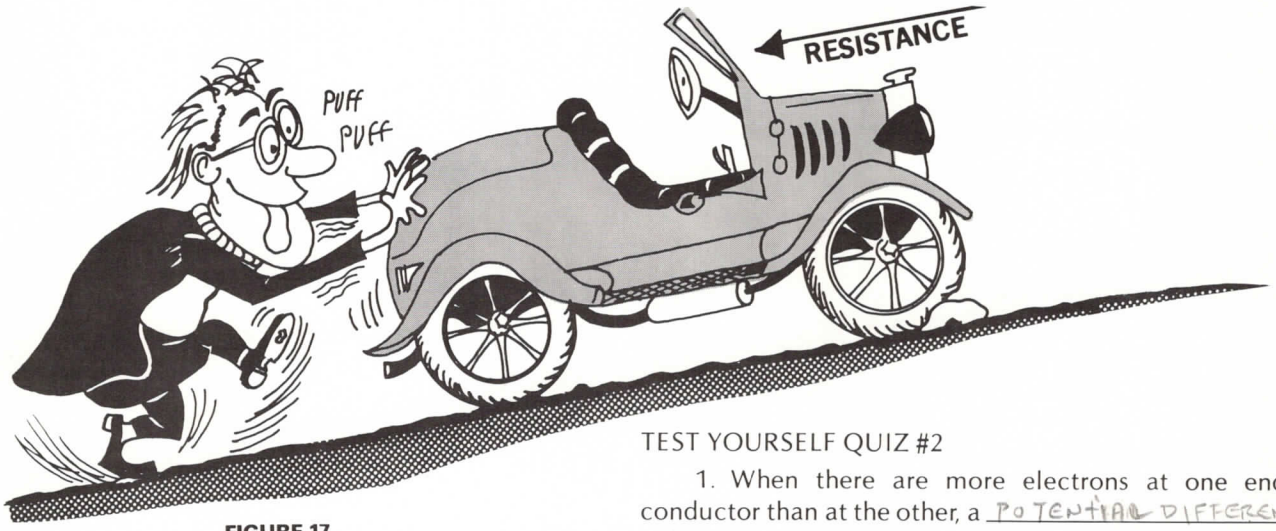


FIGURE 17

TEST YOURSELF QUIZ #2

1. When there are more electrons at one end of a conductor than at the other, a POTENTIAL DIFFERENCE -PD- exists.
2. Potential difference and electromotive force are both measured in VOLTS.
3. The flow of electrons is measured in AMPS.
4. When a circuit uses the flow of electrons to do work, the circuit RESISTS the flow of electrons.
5. A battery uses two electrodes and an electrolyte to convert CHEMICAL energy to ELECTRICAL energy.

OHM'S LAW

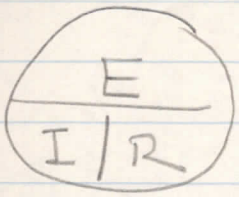
Electrons moving through a conductor behave according to certain laws. Perhaps the most often needed law of electron flow is **Ohm's Law.** Ohm's law relates potential difference measured in volts, the number of electrons passing a point in the circuit, measured in amperes and how much the circuit resists the flow of electrons, measured in ohms in this way: The current flowing in an electric circuit is directly proportional to the voltage applied to the circuit and inversely proportional to the resistance of the circuit. What this means is that, the current flowing in any circuit will depend upon voltage and resistance. For example, if the voltage applied to a circuit doubles, the current also doubles. On the other hand, if the resistance of a circuit doubles the current is cut in half.

$$\text{CURRENT} = \frac{\text{VOLTAGE}}{\text{RESISTANCE}}$$

FIGURE 18

Because the words "volt," "ampere" and "ohm" take a long time to write, these terms are frequently abbreviated.

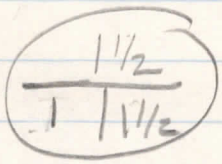
E - VOLTS - V
I - AMPS - A
R - OHMS - Ω



QUESTION

5. 1/2 VOLTS 1 AMP R=?

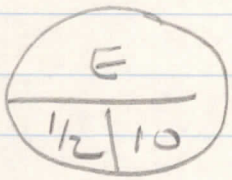
$E \div I = R$ OR $\frac{E}{I} = R$



ANSWER 1.5 OHMS

6 1/2 AMP 10Ω OR $I \times R = E$

ANSWER 5 VOLTS



7 18 VOLT 36Ω ? I

$E \div R = I$ = .5 AMPS

In working with Ohm's Law:

Volts are abbreviated E from EMF.

Amps are abbreviated I from a French word meaning intensity (of the flow.)

Ohms are abbreviated R for Resistance.

When these same terms are used in electrical circuit diagrams, different abbreviations are used:

Volts = V or v

Amps = A or a

Ohms = R or Ω

Ohm's law is often seen in the form E = I × R which means that the force needed to move electrons through a circuit is the quantity of electrons you want to have flowing times the circuit's resistance to the flow of electrons. Ohm's law is easy to remember and use if you make a chart like the one at the right.



FIGURE 19

To use this chart, notice that if you cover the terms you need to know the terms needed to calculate which you are looking for remain uncovered and in their Ohm's law relationship. For example: If you need to determine current, cover the I. Notice that what is left is E over R—so current equals E ÷ R. If you cover E to determine voltage, IR remains. So voltage is equal to I × R. Covering R tells you that resistance is figured by dividing voltage by current.

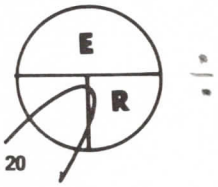


FIGURE 20

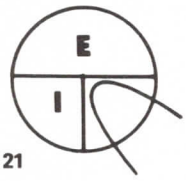


FIGURE 21



1

TEST YOURSELF QUIZ #3

1. We've left this chart for solving Ohm's law problems blank. Fill in the spaces correctly.

2. In the Ohms law chart, the letter E is used for Volts, I for Amps, and R for Resistance.

3. Other symbols you'll see will be V, A, and Ω : V stands for VOLTS, A for AMPS and Ω for RESISTANCE.

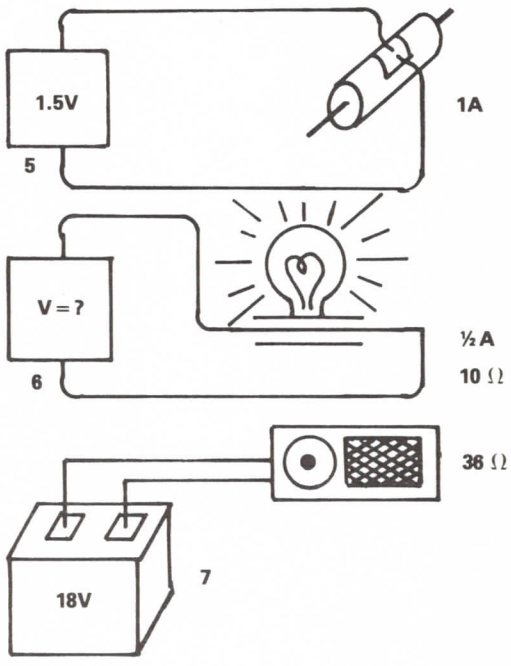
4. If you're given E and R in an Ohm's law problem, the solution to the problem will be in AMPS. "I"

5. Here is an electric motor circuit. 1½ volts powers the circuit, 1 amp of current is flowing. What is the resistance of this circuit? 1.5 OHMS

6. In this circuit, ½ amp of current is flowing and the lamp has a resistance of 10 ohms. What is the voltage of the battery? 5 VOLTS

7. This radio receiver uses an 18-volt battery. The radio's resistance is 36 Ω, so what electric current must be flowing?

1/2 AMP



ELECTRIC POWER

Electric energy in the form of electron flow is of little use if the energy cannot be used. Converting electric energy to some other form of energy is a job of the resistor in the circuit.

The resistor might be an indicator light or a motor in a clock or the heating wires in a toaster. Each of these applications of electric energy does a different amount of work. While the toaster's heating wires do a great deal of work and so require a

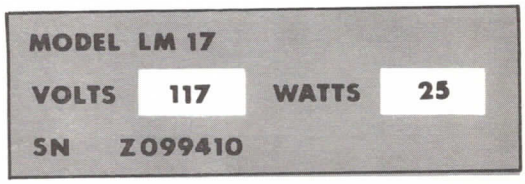


FIGURE 22

great deal of electric energy, the clock motor does little work and so needs far less electric energy.

The amount of electric energy or power needed to operate an electric device has a unit. The unit of electric power is the **watt.** A watt is a volt times an amp, or watts = E × I.

An abbreviation is often used instead of writing out watts. The abbreviation for watts is P for power, because the watt describes how much electric power is being used to do work. It's not necessary to know both current and voltage to determine watts so long as we know what the resistance of the electric circuit is. The formula for watts knowing only voltage and resistance is $P = E^2/R$. Knowing only current and resistance $P = I^2R$.

MEGA, KILO, MILLI AND MICRO

So far, all our examples have been simple ones. Only a few volts, amps and ohms. In practice, unfortunately, things are not so simple. A high voltage line used by the electric company may be operating at 38,000 volts. A small lamp such as you might see in a camera may operate at .045 amps. A meter movement, the needle of which is seen in many camera viewfinders, may have a current flow of only .000003 amps. A photocell used in some light meters might have a resistance that varies between 500 and 500,000 ohms.

Notice that these examples have a number of zeros in them. Because many electrical units contain a number of zeros, electricians and electrical engineers have adapted the prefixes used in the metric system for use in describing electrical quantities. The common prefixes used in the metric system and in electrical measurements are **mega, kilo, milli, and micro.**



The mega and kilo prefixes are used to eliminate a number of zeros by acting as a multiplier. The prefix mega in front of a unit means multiplied by one million. Kilo means multiplied by one thousand.

Milli and micro are prefixes used to indicate division. Milli means divided by one thousand. Micro, divided by one million.

To make writing an electrical measurement even easier, a shorthand, often seen on volt-ohm meters and circuit diagrams, has been developed to replace the expressions mega, kilo, milli, and micro. you'll see the expression, its abbreviation and what the expression means in the following table.

Expression	Abbreviated	Means
Mega	M	× 1,000,000
Kilo	K	× 1,000
Milli	m	÷ 1,000
Micro	μ	÷ 1,000,000

Another way of saying this is that:

1 amp is 1/1,000,000 of a megamp
1 volt is 1,000 millivolts
1 watt is 1,000,000 microwatts

The symbols used to shorten mega, kilo, milli and micro are often combined with the abbreviations covered earlier for volts, amps, and ohms. Simplifying our examples:

38,000 Volts = 38 K volts = 38 Kv
.045 Amps = 45mAmps = 45ma
.0000003 Amps = .0003 ma = 0.3ua
500,000 Ohms = 500 Kohms = 500KΩ

Getting used to these units requires time and practice, but through constant use, knowing what is meant by each abbreviation will become automatic.

TEST YOURSELF QUIZ #4

1. Electric energy is converted to other forms of energy by the RESISTANCE in the circuit.
2. Electric power, in watts, is found by multiplying VOLTS times AMPS.
3. There are 2,000 milliamps in two amps.
4. The prefix "kilo" means to MULT. by 1000.
5. .22MΩ is 22,000,000 ohms.

WATT = E X I (A VOLT X'S AN AMP)
1 MILLIAMP IS 1/1,000 AMP
M - MEGA OR MILLION - 1,000,000

THE SCHEMATIC DIAGRAM

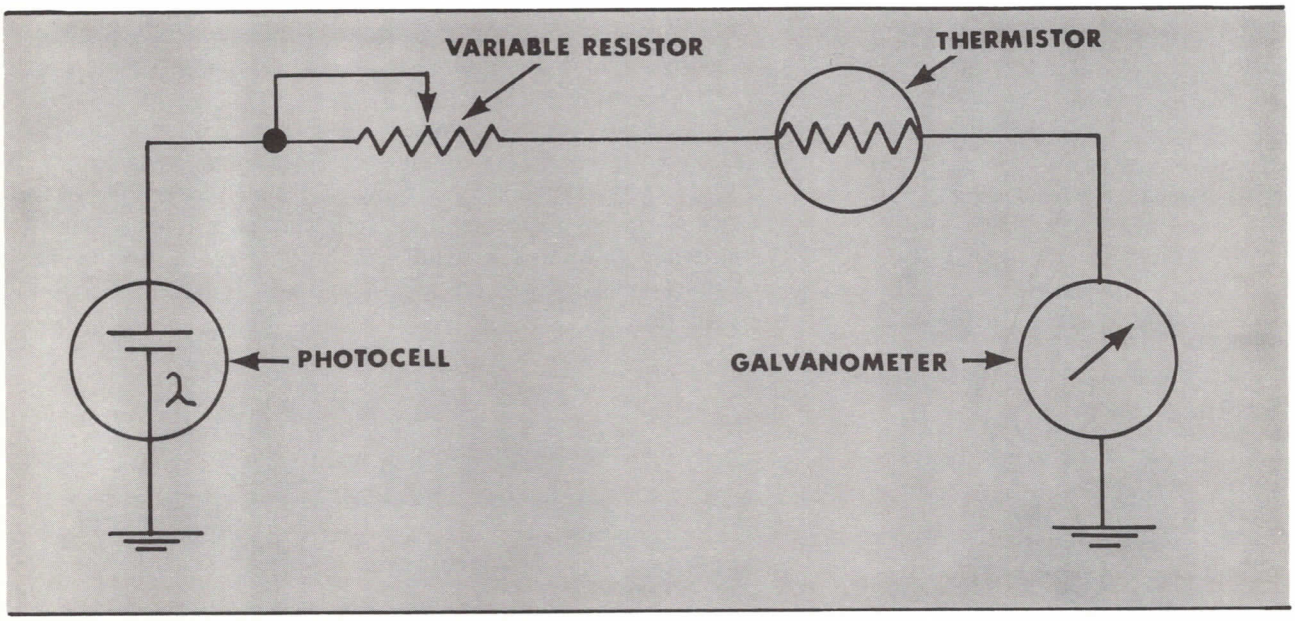


FIGURE 23

Learning the common terms and expressions used by photographers and repairmen will enable you to communicate quickly and accurately with these people. Similarly, in order to understand electricity and electronics, it is necessary to learn the language used by electricians and electrical engineers.

Probably the most baffling part of electricity to the layman is the circuit map or **schematic diagram.** The schematic diagram, frequently called just a schematic, uses a standardized set of symbols to represent the different commponents of an electric circuit. By learning the meanings of the different symbols and learning how circuits work, you will be well on your way to understanding the schematic diagram.

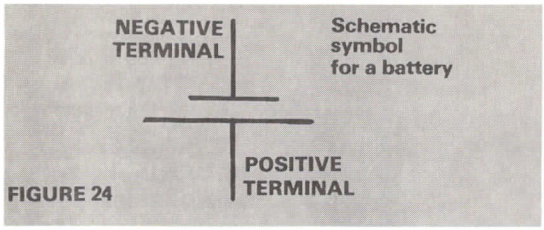


FIGURE 24

THE BATTERY

The first symbol we'll look at is the one for the battery. Since a battery has both a negative terminal and a positive terminal, the symbol for the battery shows this difference between terminals. The negative terminal is represented by the shorter line and the positive terminal is represented by the longer line.

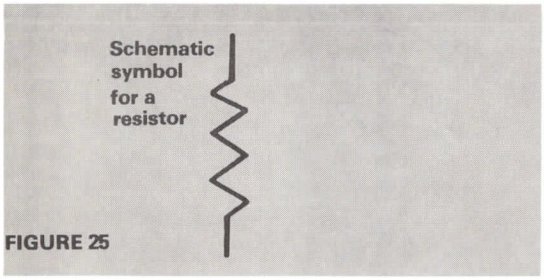


FIGURE 25

THE RESISTOR

The next symbol is the symbol for a resistor. A resistor is anything which opposes the flow of electric current. Even though many electrical devices go through a very complex process of converting electrical energy into the final product, their effect in the circuit is still the same so they may all be represented by the resistance symbol when a simple schematic diagram is drawn.

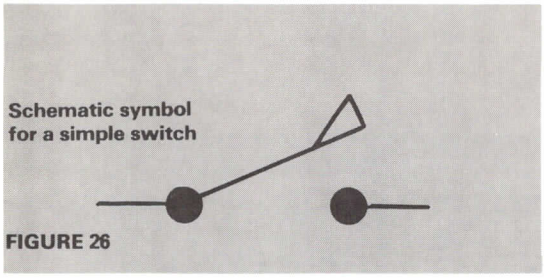


FIGURE 26

THE SWITCH

Because it's not necessary to operate most electrically powered devices all the time, most contain a switch allowing the operator to control the flow of electrons to the device. A switch may be set by the user of electricity to either allow the flow of electrons or stop the flow of electrons. Most switches depend upon the insulating property of air to prevent electrons from flowing. When electrons are flowing through a switch, the switch's metal contacts are touching. When the switch stops the flow of electrons, it's metal contacts are separated by an insulator.

A switch which is allowing electrons to flow is **closed.** A switch which is preventing electrons from flowing is **open.** When a switch is shown in a schematic diagram, it may be shown either closed—allowing electrons to flow, or open—preventing electrons from flowing.

Schematic symbol for a single pole-single throw switch.

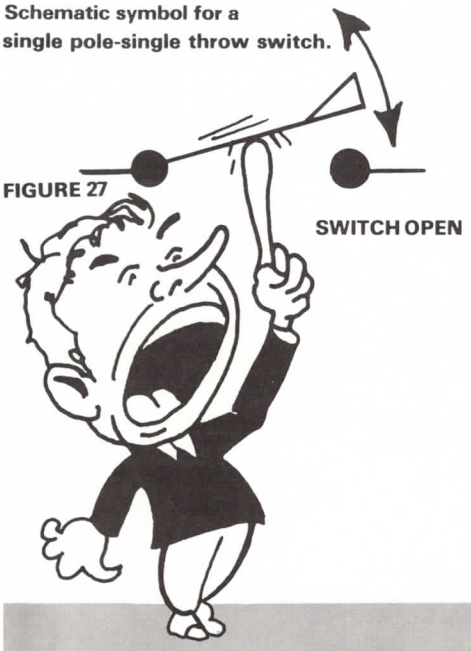
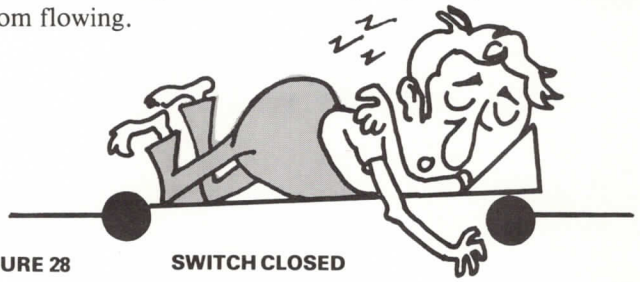


FIGURE 27


FIGURE 28 SWITCH CLOSED

The simple switch we've been looking at here is called a single pole, single throw switch. Single pole, single throw is often shortened to **spst.** We'll be taking a detailed look at switches soon.

THE CIRCUIT

In order for electrons to be put into motion by a source of voltage, we must have an electric circuit. An electric circuit is a complete path along which electrons will flow.

By adding wires between a battery, a resistor and a switch, we can construct a simple schematic diagram of a circuit that allows us to use electric energy. In this schematic diagram, the wiring being represented is very simple.

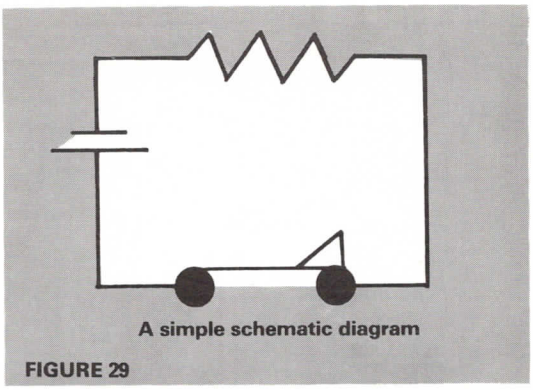
OHMS LAW

$$\frac{E}{I \mid R}$$

7. R=1.5Ω 1.5V I=? 1.5V ÷ 1.5Ω = 1 AMP
8. I = .5 E=10 ?=R 10 ÷ .5 = 20Ω
9. I = 1/4 R=100 ?=E 1/4 X 100 = 25 VOLTS
   OR .25 X 100 = 25 VOLTS
10. E=1 R=4 ?=I 1 ÷ 4 = .25 AMPS OR 1/4 AMP
11. E=2 R=10 ?=I 2 ÷ 10 = .2 AMPS

Sometimes, however, a schematic diagram must contain wires which cross each other but do not touch. That is, there is no electrical connection between the wires. In a schematic diagram when wires cross but are not connected, the wires are shown like this  or this  . Wires which do connect are shown  , the dot being used to represent an electrical connection. Once in a while, you'll see schematics using  to mean connected wires. If this is the case,  will be used for unconnected wires.

Most electric circuits, however, are not as simple as our example. Most circuits contain more than one resistance. We'll look at more complex circuits in a moment.



A simple schematic diagram

FIGURE 29

GROUNDS

Sometimes when an electric circuit is constructed, the housing for the circuit will be used as a conductor in the circuit. When the housing is used as a conductor, the circuit is said to be **grounded** to the housing. The term **ground** in this sense is a carryover from the early days of electronics. In early circuits, a grounded connection was just that—a wire connected to a conductor driven into the ground. Although strictly speaking a grounded circuit is connected to the earth, it's common to call any connection to a circuit housing or chassis, a ground.

Schematic symbols for ground



FIGURE 30

TEST YOURSELF QUIZ #5

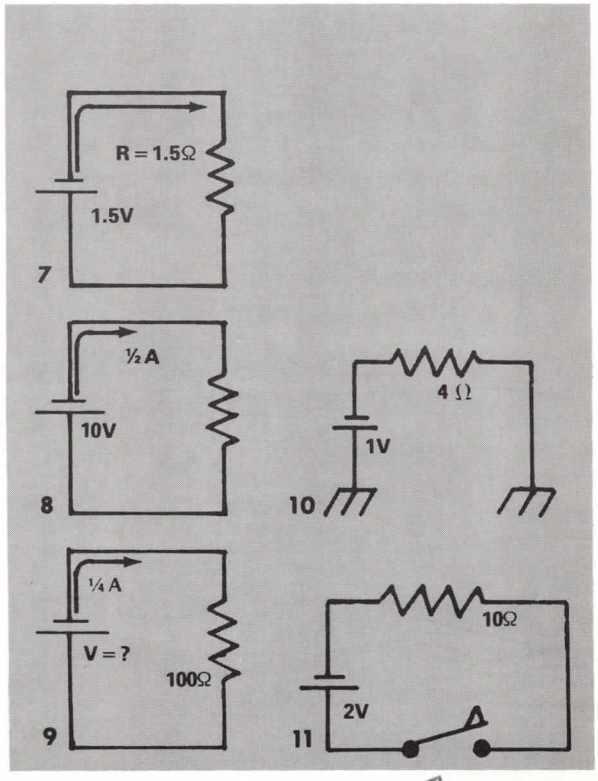
What do these schematic symbols stand for?

1.  BATTERY
2.  OPEN SPST SWITCH
3.  CHASSIS GROUND
4.  UNCONNECTED WIRES — A WIRE CROSSING TWO UN-CONNECTED
5.  RESISTOR
6.  CONNECTED WIRES — CONNECTION-WIRE

OHM'S LAW PROBLEMS

In the following problems we'll be using schematic diagrams to represent actual circuits. To solve each probelm, you'll need to analyze the schematic diagram.

7. What is the current in this circuit? 1 amps
8. What is the resistance of R? 20 ohms
9. What voltage is provided by the battery in this circuit? 25 volts
10. Calculate the current flowing in this circuit. I = .25 amps.
11. In this circuit, how much current is flowing through the 10 Ω resistor? I = 0 amps. SWITCH IS OPEN



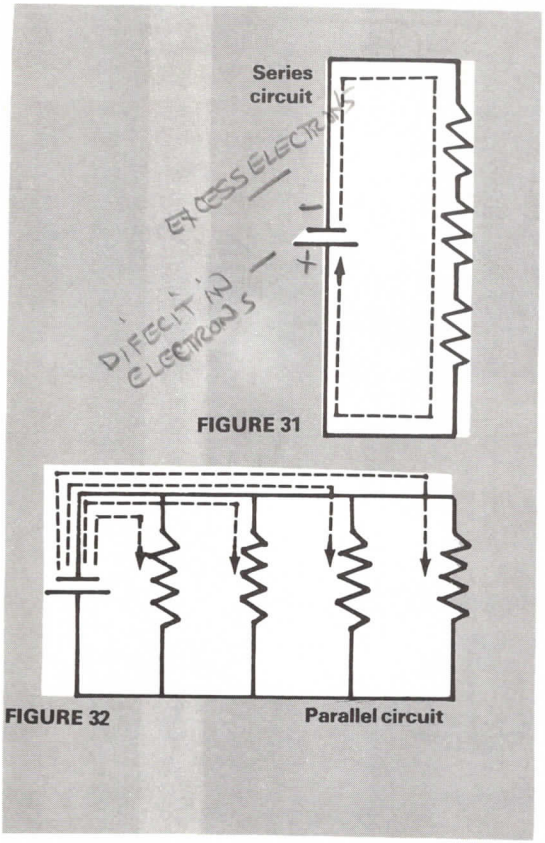


FIGURE 31

FIGURE 32

SERIES AND PARALLEL

When a circuit contains more than one resistance, the circuit may be wired in either of two ways. The resistances in the circuit may be wired in **series** or they may be wired in **parallel.** Let's look at a series circuit first.

Notice in the series circuit that the flow of electrons is into the circuit from the negative terminal of the battery, through each of the components, and finally out of the circuit and to the positive terminal of the battery. That is, electrons which enter the circuit must pass through every component in the circuit before they leave the circuit.

In the other circuit, the parallel circuit, notice that there is more than one current path. Electrons going to the first resistor pass through it and then return to the battery. Other electrons go to the second resistor and back to the battery and so on for additional resistors in parallel.

KIRCHOFF'S LAWS

Because both series and parallel circuits operate in a predictable manner, laws have been formulated which describe the operation of series and parallel circuits. Two of these laws, **Kirchoff's voltage law** and **Kirchoff's current law** are useful to technicians working on photographic equipment.

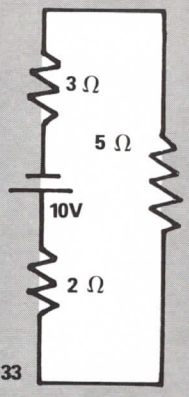


FIGURE 33

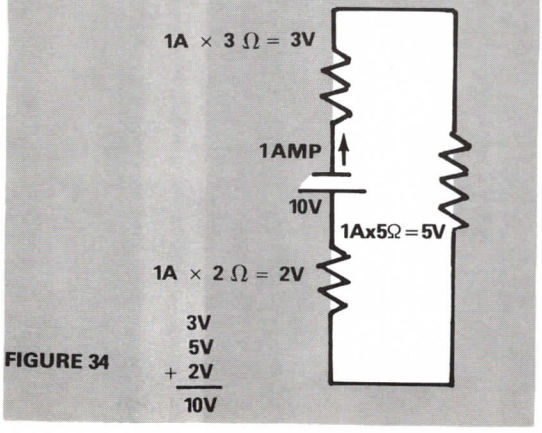


FIGURE 34

THE VOLTAGE LAW

Kirchoff's voltage law is easy to see in series circuits. Using Ohm's law, let's examine a series circuit to see what Kirchoff's law tells us. In this circuit, three resistances are connected in series with a 10-volt battery. Because this is a series circuit, the battery looking into the circuit sees the sum of the resistances, or 10 ohms. Using Ohm's law, we calculate the current in the circuit:

10 volts ÷ 10 ohms = 1 amp

One amp flowing into the circuit and one amp flowing out of the circuit because, remember when an electron is pushed in at one end of the circuit, one must come out the other. For this reason, this circuit must have one amp flowing through each of its resistances.

Using Ohm's law for each of the resistors, we calculate the voltage we would expect to measure across each resistor. Ohm's law tells us that

1 amp × 3 Ω = 3 volts.

This means that we would measure 3 volts. A similar calculation for the other resistors gives 5 volts measured from one side of the 5-ohm resistor to the other, and 2 volts across the 2-ohm resistor. Notice that the sum of these voltages is the same as the voltage

which has been applied to the circuit.

Simplified, Kirchoff's Law says that the sum of the voltage drops in a series circuit will equal the voltage applied to the circuit. Analysis of a series circuit to determine Kirchoff's voltage law has revealed two other rules which apply to a series circuit. In every series circuit, the current in one point of a circuit will be the same as the current in every other point of the circuit. Also, the total resistance of a series circuit, or the resistance the battery would see looking into the circuit, is the sum of all the resistances in the circuit. As a simple formula, total resistance for a series circuit (written R_t) is equal to the sum of the resistors in series. So, $R_t = R_1 + R_2 + R_3 + R_n$ where R_n is the last of however many resistors are connected in series.

THE CURRENT LAW

Next, examine the schematic diagram of the parallel circuit. Notice that the resistors in the parallel circuit are connected in a different manner from the resistors in the series circuit. Because of the way the resistors are wired to the battery, current which enters the circuit can go through either the 2-ohm or the 5-ohm resistor. In an actual electrical circuit wired in this manner, an electric current would be leaving the battery and then dividing into a current going through the 2-ohm resistor and current going through the 5-ohm resistor.

Also notice in this circuit that the pressure applied by the battery is the same across the 2-ohm resistor and the 5-ohm resistor. Because the pressure applied by the battery to each resistor is the same, yet the current for each resistor is independent of the other, we can for the moment look at the two components in this parallel circuit as separate circuits.

Look at the redrawn schematic. Through the 2-ohm resistor on the left-hand side of the circuit, 5 amps of current will be passing. Through the 5-ohm resistor, the current flow will be 2 amps. Both resistors are connected to the same battery so that the total current must come out of and go back into the same battery.

The total current of 7 amps comes out of the battery and goes to the junction point in the circuit where the resistors are connected. At the junction point, the 7-amp current splits into a current of 5 amps and a current of 2 amps. After the 5-amp current passes through the 2-ohm resistor and the 2-amp current passes through the 5-ohm resistor, the two currents recombine into a 7-amp current. The 7-amp current returns to the battery. This example has led us to Kirchoff's current law. Kirchoff's current law says that the amount of current going into a circuit must be the same as the amount of current leaving the circuit.

Notice that if Ohm's law is applied to the same circuit we've used to demonstrate Kirchoff's current law,

Resistance = E/I = 10V ÷ 7A, or about 1.4Ω .

So the resistance seen by the battery is lower than the resistance of either of the individual resistors.

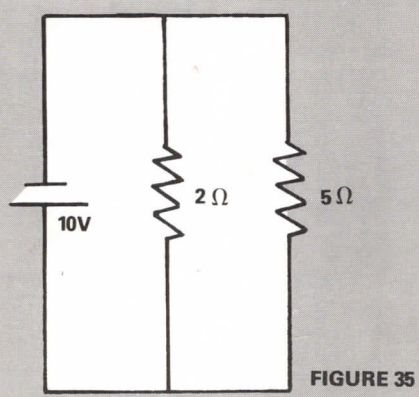


FIGURE 35

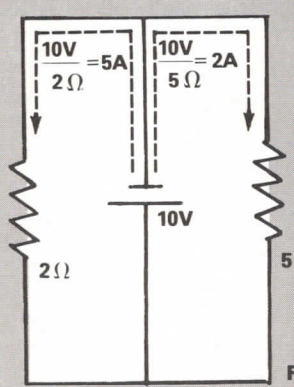


FIGURE 36

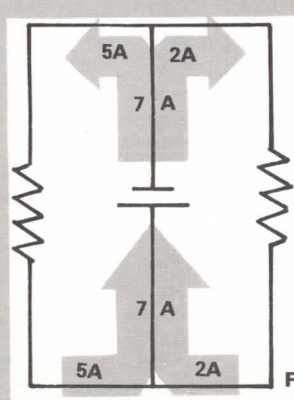


FIGURE 37

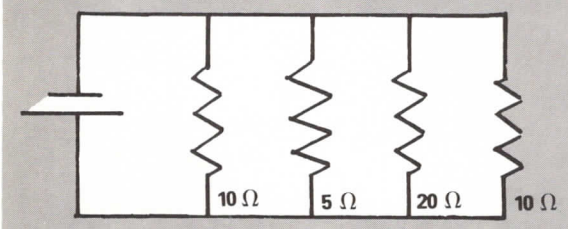


FIGURE 38

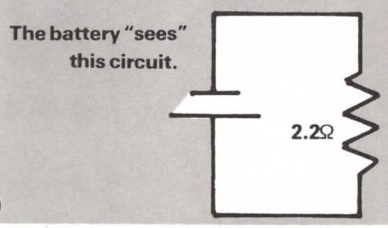


FIGURE 39

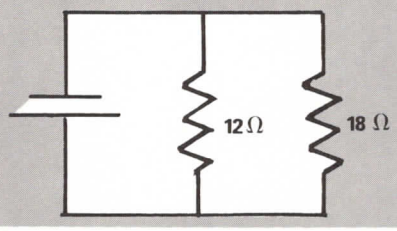


FIGURE 40

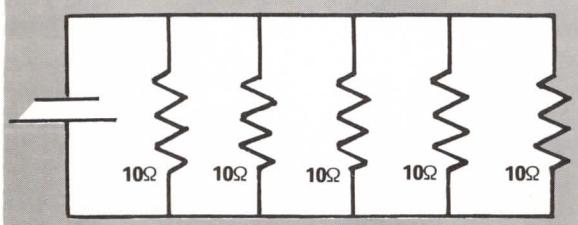


FIGURE 41

EQUIVALENT RESISTANCE

In any parallel circuit, no matter how many resistances are connected in parallel, the **equivalent resistance** seen by the battery will be less than that of any individual resistance. Because it's seldom convenient to calculate total current in order to find equivalent resistance, a formula which eliminates the intermediate steps has been derived for a circuit with any number of resistances in parallel. The equivalent resistance (R_{eq}) is found by using this formula:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_n}$$

Here is an example of how this formula works:

What equivalent resistance will a battery see when connected to this circuit?

$$1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$$
$$1/R_{eq} = 1/10 + 1/5 + 1/20 + 1/10$$

to add fractions, we must have a common denominator, so:

$$1/R_{eq} = 2/20 + 4/20 + 1/20 + 2/20$$
$$1/R_{eq} = 9/20 \text{ so } R_{eq} = 20/9 \text{ or } 2.2\ \Omega$$

When you have only two resistances in parallel, you may use a simpler formula:

$$R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2}$$

Here is an example:

$$R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_{eq} = \frac{12 \times 18}{12 + 18}$$

$$R_{eq} = \frac{216}{30}$$

$$R_{eq} = 7.2\ \Omega$$

In a few cases you'll find that all the resistors in parallel are of equal value. If this is the case, to find the equivalent resistance, divide the value of one resistor by the number of resistors.

For example:

$$\frac{10}{5} = 2\ \Omega$$

Proof: $1/R_{eq} = 1/10 + 1/10 + 1/10 + 1/10 + 1/10$

$$1/R_{eq} = 5/10$$
$$R_{eq} = 10/5 = 2\ \Omega$$

NOTE:

KIRCHOFF'S LAWS

EQUIVALENT RESISTANCE

S. 2 18Ω RESISTORS IN PARALLEL

$\frac{1}{Req} = \frac{1}{18} + \frac{1}{18} = \frac{2}{18}$ $18 \div 2$ 9Ω

~~100~~

$\frac{R1 \times R2}{R1 \times R2}$

~~400~~ 200

2

$\frac{10K\Omega}{2} = 5K\Omega$

$\frac{10K \times 10K}{10K + 10K}$ $\frac{100K}{20K}$

TEST YOURSELF QUIZ #6

1. A circuit that provides only one path for electrons is called a SERIES circuit.
2. One of Kirchoff's laws says that the sum of the VOLTAGE DROP in a series circuit will equal the VOLTAGE applied to the circuit.
3. Using one of Kirchoff's laws, solve this problem. →
4. 2 amps of current goes into this circuit, so 2 amps of current leave the circuit.
5. The total resistance which a battery sees looking into a series circuit is the SUM of all the resistance.
6. What is the current leaving the battery in this circuit?
   Total Current = 8.5 amps.

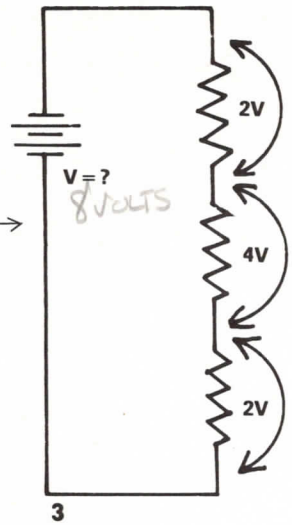
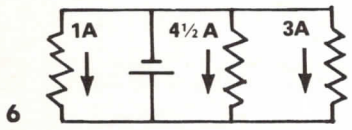
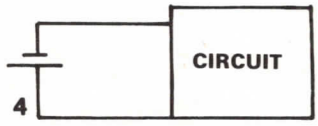




FIGURE 42 340 cells connected in series to make a 510 volt photoflash battery.





USING MORE THAN ONE CELL

The common dry cell (zinc-carbon cell) can provide 1½ volts of potential difference. Other common cells provide slightly different voltages. The lead-acid cell provides 2 volts, the mercury cell 1.35 volts and the nickel-cadmium cell 1.25 volts.

Although each of these cells is useful in a number of applications, quite often a circuit needs a higher voltage than is provided by a single cell. To provide higher voltages, individual cells are connected in series. When cells are connected in series, the voltages of the cells are added.

When cells are connected in series, each cell's positive terminal is linked to its neighbor's negative end. For example—two 1½ volt cells connected in series provide 3 volts, six lead acid cells connected in series provide 12 volts.

Sometimes cells are connected in parallel. Cells connected in parallel are always connected with all positive ends joined together for one terminal and all negative ends connected together for the other. When cells are connected in parallel, the current available is multiplied by the number of cells in parallel, but the voltage remains that of one cell. So if one cell can provide only one amp (6.24 quintillion electrons per second), two cells in parallel can provide twice as many electrons (12.48 quintillion electrons per second)

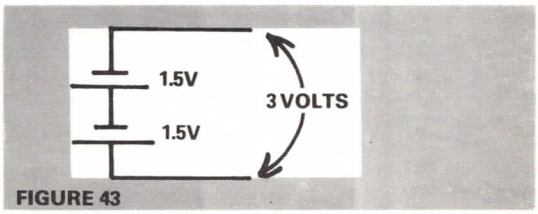


FIGURE 43

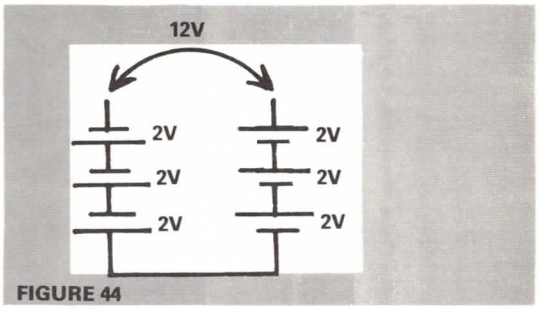


FIGURE 44

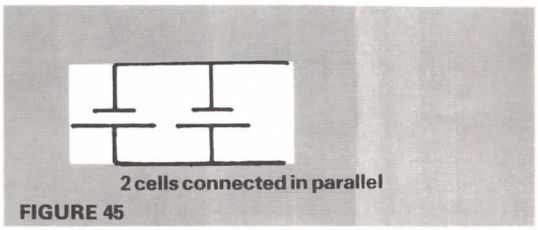


FIGURE 45

SUBSCRIPTS

In the examples so far, all the circuits have been very simple, containing a few resistances, one source of power and a switch. Most electrical devices have much more complicated circuits, however. Frequently, there will be many resistors as well as other electrical components. For this reason, electrical engineers have developed a method of identifying individual components based upon a letter describing what the component does and a number identifying the individual component.

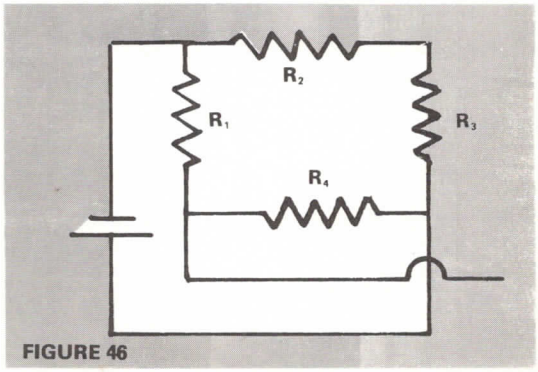


FIGURE 46

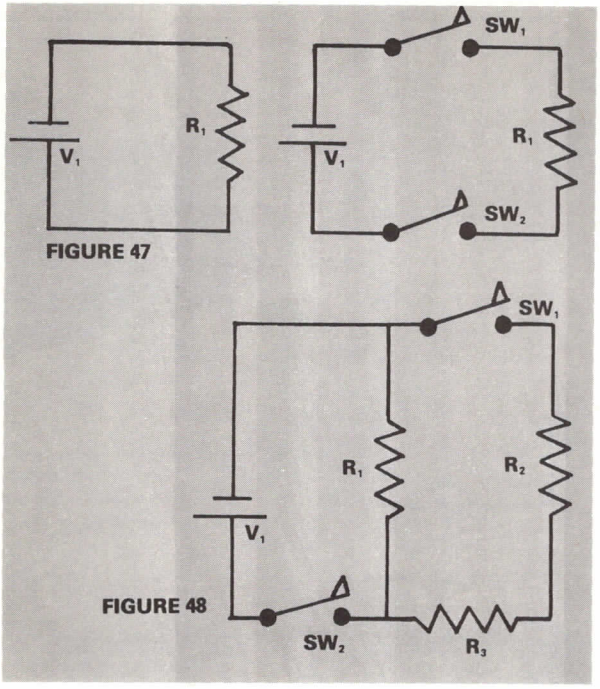


FIGURE 47

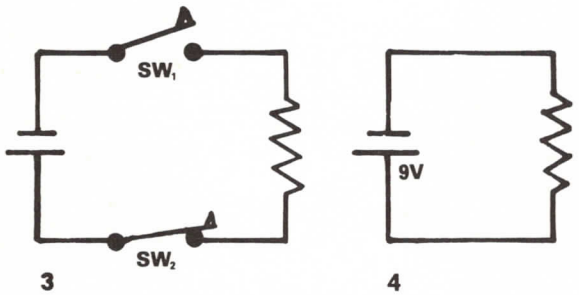
FIGURE 48

For example, in the circuit containing many resistors, each resistor would be identified by the letter R. Following the R identifying the component as a resistor would be a number: 1, 2, 3, 4...this number is called a **subscript.**

Subscripts are also used with other components. Voltage sources V_1, V_2, etc., switches SW_1, SW_4, SW_9, etc. The subscript provides a way for the person who designs the circuit to describe each component. The subscript also provides a way for the person reading the schematic to identify each component. For example, we might see a simple circuit drawn schematically like this.

R_1 5Ω
R_2 22Ω
R_3 47Ω
SW_1 SPST
SW_2 SPST
V_1 1½ volt cell

A subscript may also be in the form of a letter: R_a, R_b, SW_a, for example.

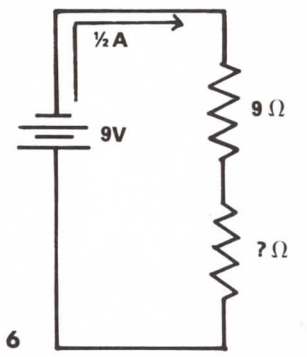


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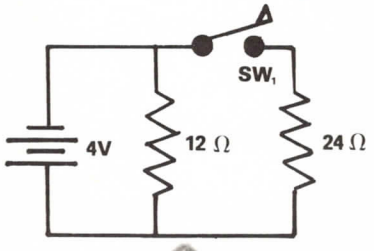
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TEST YOURSELF QUIZ #7

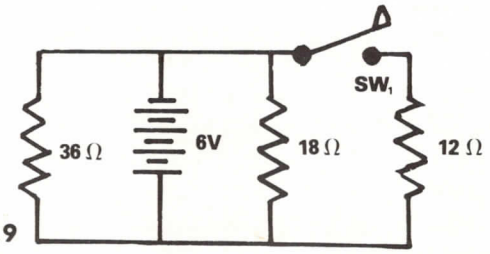
1. The voltage of the mercury cell is 1.35 volts. Three mercury cells connected in series will provide 4.05 volts.
2. Three mercury cells connected in parallel will provide 1.35 volts.
3. In this circuit, SW_1 is OPEN (open, closed), while SW_2 is CLOSED (open, closed).
4. If zinc carbon cells are used to power this circuit, how many cells will be used to make up the battery? 6
5. Two 18-ohm resistors are in parallel. Use the parallel resistance equation to find their equivalent resistance. 9 OHMS
6. The unknown resistance is in series with the 9-ohm resistor so the values are added. What's the total resistance of this circuit? 18 ohms.
7. With SW open, the total current in this circuit is 1/3 amps. When SW is closed the equivalent resistance is 8 ohms.
8. When SW_1 is open, this circuit's equivalent resistance is 12 ohms.
9. When SW_1 is closed, the equivalent resistance is 6 ohms.



6



7

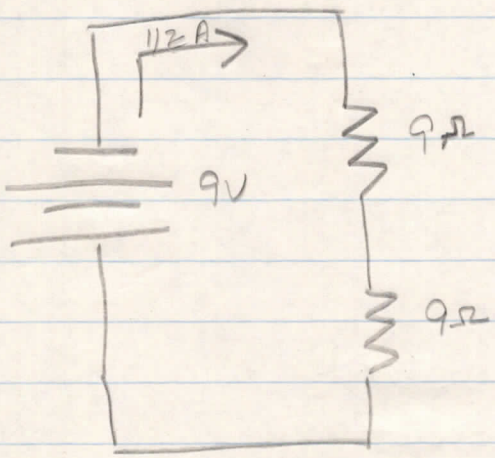


8,9

READ CAREFULLY

6. E / I|R

E = 9V
I = 1/2A
9V ÷ .5A = 18OHMS



7. (1) E = 4V 4V ÷ 12Ω = .3333 - A OR 1/3AMPS
R = 12Ω
I = ? A

(2) $\frac{1}{R_{eq}} = \frac{1}{12} + \frac{1}{24}$ OR $\frac{R_1 \times R_2}{R_1 + R_2}$

$\frac{12 \times 24}{12+24} = \frac{288}{36} = 8\Omega.$

8. (1) $\frac{1}{R_{eq}} = \frac{1}{36} + \frac{1}{18}$ OR $\frac{36 \times 18}{36+18}$ OR $\frac{648}{54} = 12\Omega$

9. (2) $\frac{1}{R_{eq}} = \frac{1}{36} + \frac{1}{18} + \frac{1}{12}$ OR $\frac{1}{36} + \frac{2}{36} + \frac{3}{36} = \frac{6}{36}$ OR 6Ω

ALTERNATING CURRENT

Up to this point, all the electrical circuits we have studied have relied on direct current to make them operate. **Direct current** is a continuing flow of electrons going one direction. In a direct-current circuit, an electron which enters the circuit as the excess electron will eventually emerge from the other end of the circuit. But not all electrical circuits are operated by direct current as is provided by a battery or a photocell. Many electrical devices depend instead upon **alternating current.** Fortunatly for the technician, in simple circuits alternating current behaves the same way as direct current.

Because direct current is not a very efficient way to transmit electric power over long distances, most electric power which is transmitted from electric generating stations to homes, factories, businesses and other users of electricity, is supplied in the form of alternating current. While direct current provides an uninterrupted pressure on the electron in one direction, alternating current applies pressure on the electrons in the conductor first for electron flow in one direction and then for electron flow in the other direction. If you looked at one electron in a conductor, you would see that it never makes it from one end of the circuit to the other. Rather, the individual electron moves back and forth within a very small segment of the wire.

Although a complicated circuit using batteries and switches could be made to produce alternating current, there's a much easier way of producing AC or alternating current. The machine used to produce alternating current electricity for many applications is call the **alternator** (sometimes also referred to as a **generator**). The alternator is a device that converts mechanical energy into electrical energy in the form of alternating current.

A simple graph showing voltage in an alternating current circuit might look something like this.
First the voltage swings to its peak in one direction, then back to zero, then to its peak in the other direction, and once again to zero. This moves an electron in the wire first in one direction and then in the other.

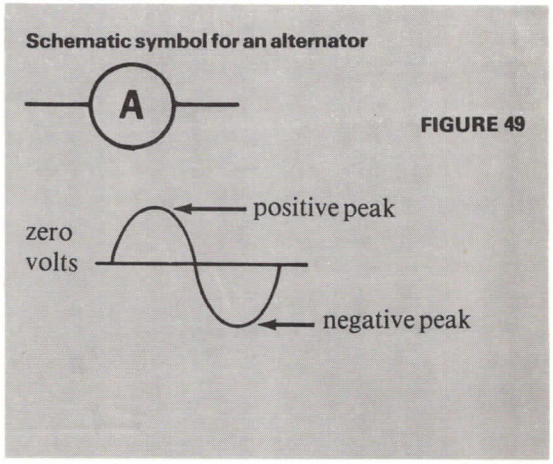


FIGURE 49

THE HERTZ

A complete voltage swing from zero to positive peak to zero then to negative peak and to zero again is known as one **cycle.** By using a suitable measuring device in any alternating current circuit, it's possible to count the number of cycles which occur during one second. For example, if you have a device for counting the number of cycles per second in the electric current supplied to your home, you will find that 60 cycles are completed in one second. The number of cycles occurring in one second is known as **frequency,** and the unit for frequency is **hertz.** So, the electric power supplied to your home has a frequency of 60 hertz (Hz).

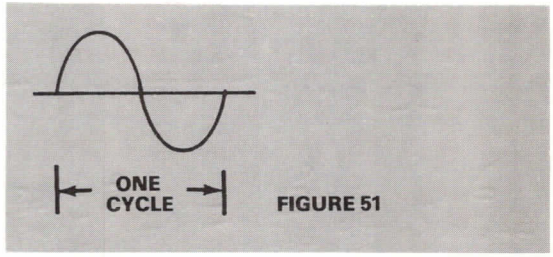


FIGURE 51

In addition to being able to be easily transmitted over long distances, alternating current electricity will operate some

Power transformers.

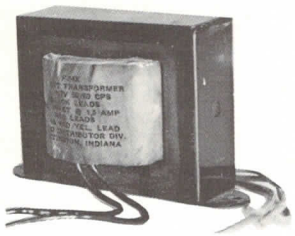


FIGURE 52

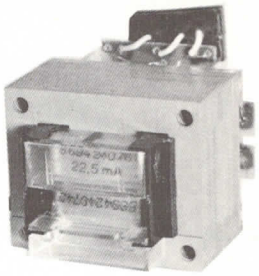


FIGURE 53

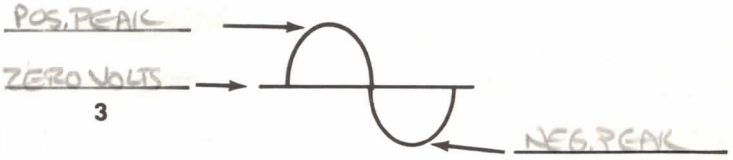
electrical devices which won't function on direct current. One of these devices is the **transformer.** The transformer takes alternating current supplied to two of its connections and either increases (steps up) or decreases (steps down) the voltage of this electricity at its other connections. Transformers are often seen in photographic equipment where a lower voltage than that supplied by the alternating current electricity available to the photographer is needed.

TEST YOURSELF QUIZ #8

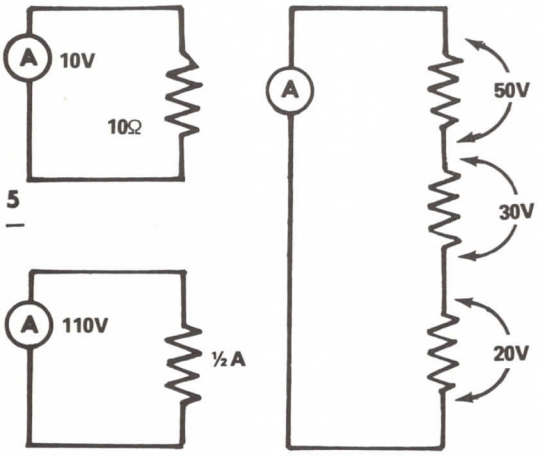
1. DC (Alternating current, Direct current) is seldom transmitted over long distances because AC (alternating current, direct current) is transmitted much more efficiently.

2. In an alternating-current circuit, an individual electron moves BACK and FORTH instead of from one end of the circuit to the other.

3. Label this graph of voltage in an alternating current circuit.



3



4. The number of cycles occurring in one second is known as FREQUENCY which is expressed in HERTZ.

5. What is the current flowing in this circuit? 1 amps.

6. What is the electric power being used in this circuit? 55 watts.

7. What voltage is the alternator establishing across this circuit? Voltage = 108 v.

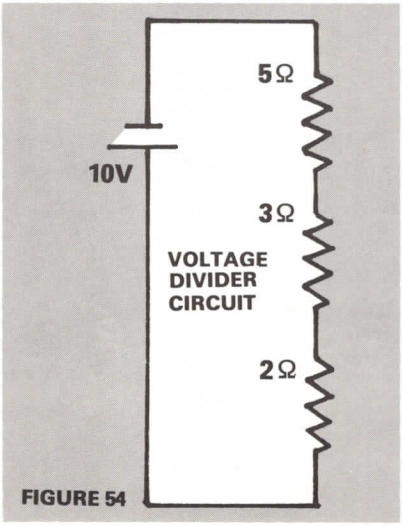


FIGURE 54

THE VOLTAGE DIVIDER

Remember Kirchoff's voltage law that the sum of the voltages in a series circuit must equal the supply voltage. Now imagine photographic equipment which needs 10 volts to operate some parts, 5 volts for others, 3 volts for others and possibly 2 for other portions of the circuit. By making a **voltage divider,** like the one shown here, each of the necessary voltages may be taken from the higher voltage.

Although this voltage-divider circuit could be manufactured and used, it is not a very practical circuit because it has a lot of current passing through it. Most voltage dividers operate in a current range of much less than one amp. Most often, resistors with a fixed resistance are used in circuits like this.

5. (E / I R) $E = 10V$, $R = 10\Omega$.

$10V \div 10\Omega = 1$ AMP

6 WATTS = E X I WATTS (P) VOLTS + AMPS

WATTS = OR $P = E^2/R$ VOLTS + OHMS

$P = I^2R$ AMPS OHMS
CURRENT + RESISTANCE

6 - $110V \times .5A = 55$ WATTS

KIRCHOFF'S LAW

7. SUM OF THE VOLTAGE DROPS IS EQUAL TO THE VOLTAGE APPY'D.

FIXED RESISTORS

Fixed resistors are manufactured a number of different ways. The most common type of fixed resistor is the **carbon-composition** type in which a special carbon compound is insulated by a ceramic jacket except for a wire connected to each end. The carbon-composition resistor is easy to manufacture and can be made to close enough tolerance for most circuits. Because the carbon-composition resistor works well and is inexpensive, you will see it in a lot of circuits.

Another type of resistor you'll encounter often is the **metal-film resistor.** Metal-film resistors are constructed of a spiral of resistance element deposited on an insulating support.

The spiral of resistance element is capped on each end and then the body of the resistor is covered with an insulating material. Because the manufacturing of metal-film resistors allows for precise controls, most metal-film resistors are precision resistors. Metal-film resistors are often made so that they will vary less than 1% from their marked resistance.

However, metal-film resistors pay a price for their precision. Metal-film resistors are quite heat-sensitive. In fact, careless soldering can easily damage a metal film resistor. Fortunately. metal-film resistors are easy to recognize due to their "dog-bone" shape. You'll always want to be extra careful when working with metal-film resistors.

Another type of precision resistor is made from a length of special wire wound on a support. A resistor made of wire wound on a support is called a **wirewound resistor.** Because the length of the wire may be very accurately controlled, most wirewound resistors are precision resistors. A precision resistor will not vary much from its marked value. A typical precision resistor may be no more than 1 or 2 percent from its marked value.

Wirewound resistors are also used in some applications where the resistor must be able to dissipate a large amount of electric energy as heat energy. Resistors which dissipate more than five watts are frequently wire wound.

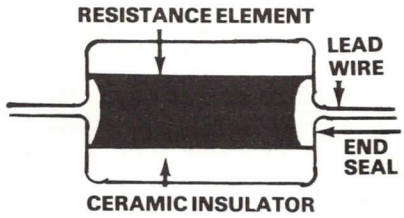


FIGURE 55

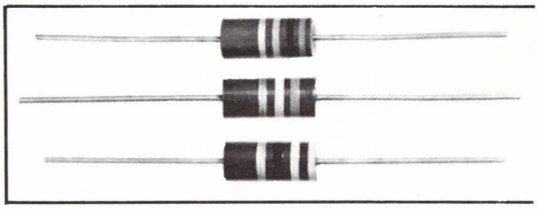
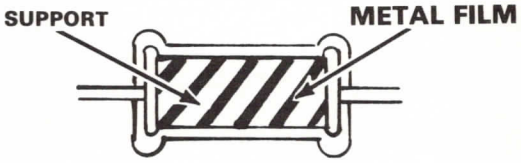


FIGURE 56 Carbon composition resistors.



Internal construction of a metal-film resistor

FIGURE 57

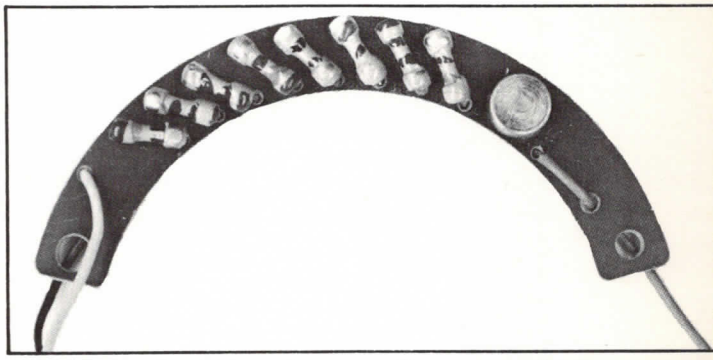


FIGURE 58 Metal film resistors used in a camera circuit.

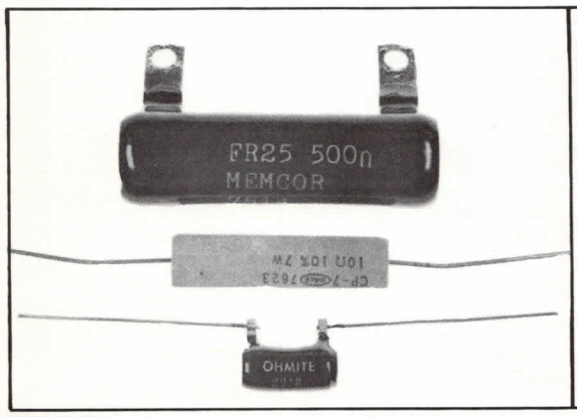


FIGURE 59 High power wirewound resistors.

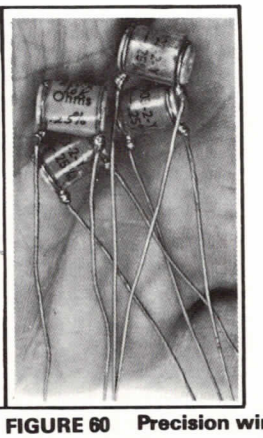


FIGURE 60 Precision wirewound resistors.

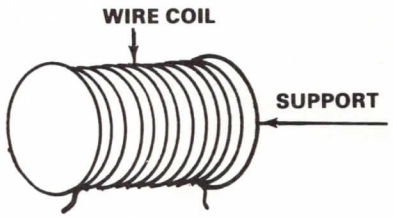


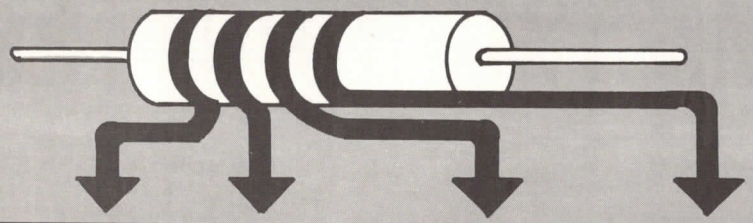
FIGURE 61
Construction of a wirewound resistor

THE RESISTANCE COLOR CODE

Because it's necessary to have some means of telling what resistance a resistor has without having to remove the resistor from the circuit and make a measurement, a color code has been developed. The table and the examples show the numbers which correspond to each color and how the color code is used to make a resistance reading.

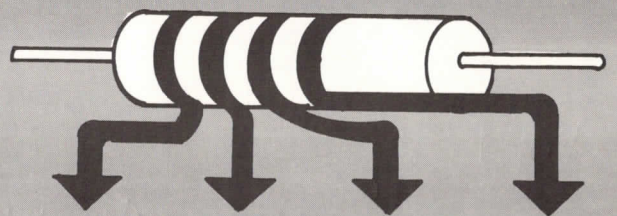
If resistors have a fourth band, the fourth band is called a **tolerance band.** The tolerance band tells the allowable error in the resistance of the resistor. Usually resistors are allowed an error of from five to twenty percent from their marked value. A fourth band of gold indicates a resistor will vary from its marked value by less than five percent. A fourth band of silver indicates a resistor will be within ten percent of its marked value. If there's no band, the resistor will be within twenty percent of the value indicated by its color code.

RESISTANCE COLOR CODE



COLOR	1st BAND	2nd BAND	MULTIPLIER BAND	TOLERANCE
BLACK	0	0	× 1	
BROWN	1	1	× 10	
RED	2	2	× 100	
ORANGE	3	3	× 1000	
YELLOW	4	4	× 10,000	
GREEN	5	5	× 100,000	
BLUE	6	6	× 1,000,000	
VIOLET	7	7	× 10,000,000	
GRAY	8	8	× 100,000,000	
WHITE	9	9	× 1,000,000,000	
GOLD			÷ 10	5%
SILVER			÷ 100	10%
NONE				20%

HOW TO READ THE COLOR CODE



RED 2 — YELLOW 4 — ORANGE × 1000 — SILVER 10%

24000 Ω ± 10%

ORANGE 3 — VIOLET 7 — BLACK × 1 — SILVER ± 10%

37 Ω ± 10%

WHITE 9 — BROWN 1 — BROWN × 10 — GOLD ± 5%

910 Ω ± 5%

GREEN 5 — VIOLET 7 — GRAY × 100000000 — NONE ± 20%

5,700,000,000 Ω ± 20%

BROWN 1 — BLACK 0 — GOLD ÷ 10 — GOLD ± 5%

1.0 Ω ± 5%

BLUE 6 — GRAY 8 — SILVER ÷ 100 — GOLD ± 5%

.68Ω ± 5%

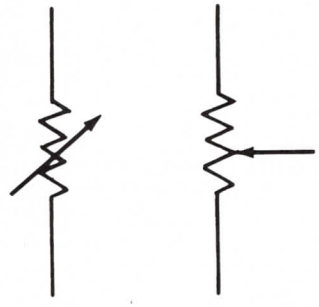
VARIABLE RESISTORS

Some applications of resistors require that it be possible to change the resistance in the circuit. Because it is seldom practical to remove one resistor from a circuit and connect another, the **variable resistor** is used.

A variable resistor is a resistor which has a resistance element along which a moveable contact or brush moves. The brush may be stopped at any point along the resistance element to obtain different resistances from the variable resistor.

The resistance element in a variable resistor may be made of a carbon composition or out of resistance wire. Carbon-composition variable resistors are used in many low-power circuits while wirewound variable resistors are used in high-power circuits.

Variable resistors are constructed with either two or three terminals. Variable resistors with only two terminals are commonly called **rheostats.** A rheostat is used to control current flow. A variable resistor which has three terminals is called a **potentiometer.** A potentiometer is most often used as a voltage divider. Because the word "potentiometer" takes a long time to write, it's frequently abbreviated "pot." Most schematic diagrams use the expression **pot** instead of potentiometer.



Schematic symbols for variable resistors

FIGURE 62

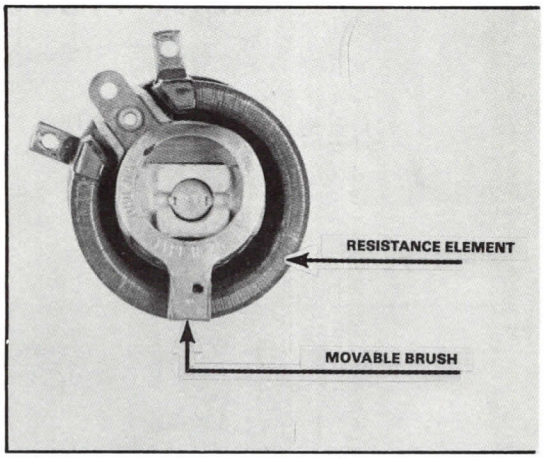
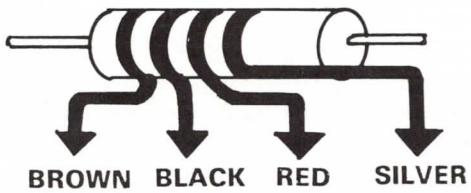


FIGURE 63 A wirewound variable resistor.

TEST YOURSELF QUIZ #9

1. Some resistors are quite heat-sensitive. For this reason you'll have to be extra careful when working with METAL FILM resistors.

2. This resistor, if checked with an ohmmeter would read 1000 ohms with no more than 10 % error.



3. A resistor marked red, brown, orange should read 21KΩ.

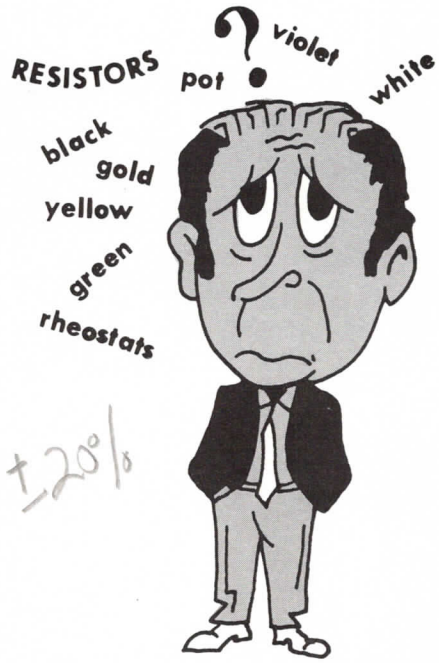
4. A resistor marked green, red, yellow should read 520KΩ.

5. A resistor marked yellow, yellow, black should read 44Ω.

6. A resistor marked white, black, black should read 90Ω.

7. A resistor marked violet, green, gold should read 7.5Ω.

±20%



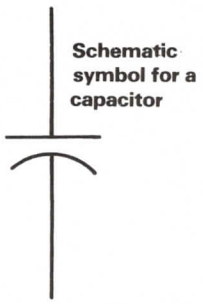


FIGURE 64

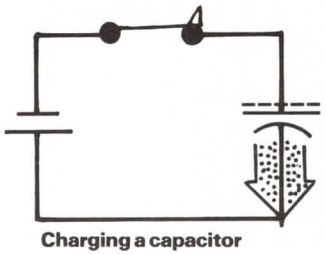


FIGURE 65

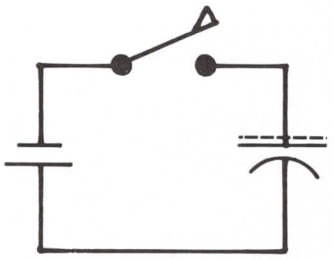


FIGURE 66 Charged capacitor

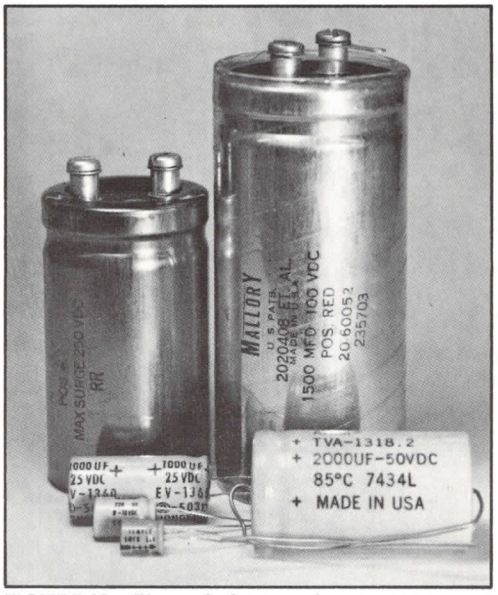


FIGURE 68 Electrolytic capacitors.

CAPACITORS

The capacitor is an electrical device that may be used to store an electrical charge for a period of time. Capacitors are constructed of two conductors separated by an insulator. When a capacitor is connected to a DC voltage, it's impossible for electrons to get across the insulator. Despite electrons not being able to cross the insulator barrier, capacitors are useful in direct current circuits. Here's why. Although a current will not flow through a capacitor, a voltage connected across a capacitor will cause electrons to be pushed onto one of the capacitor's plates and be pulled from the other plate.

Pushing electrons onto one plate and pulling them from the other creates a potential difference between the capacitor's plates. When the DC voltage is removed from the capacitor, the capacitor's plates retain their potential difference. Most capacitors used in electronic-flash units can hold a charge for many weeks.

The amount of charge which can be accumulated by a capacitor is measured in **farads.** Because a farad is a very large unit, most capacitors are rated in microfarads (ufd).

In addition to micro, another prefix is often used with the unit farad. This is the prefix **pico.** A picofarad is one trillionth of a farad. Although a trillionth of a farad doesn't sound like much, capacitors of a few picofarads are becoming common in modern circuits. In addition to their capacitance, most capacitors have a voltage rating. The voltage rating gives the maximum safe operating voltage for a capacitor. So, for example, you might see a capacitor marked 1.5 ufd, 350V. This would be a capacitor of 1.5 microfarads designed to operate safely up to 350 volts.

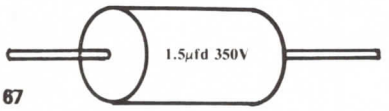


FIGURE 67

Capacitors are commonly identified by the type of insulating material they use. Mica, mylar, ceramic, paper and electrolytic capacitors are all in use in circuits you'll be seeing. The type of capacitor used will depend upon the purpose of the circuit.

Mica capacitors are often used in very high voltage circuits. Mylar and ceramic capacitors are used when high voltages will not be encountered. Paper capacitors, although seldom used in photo equipment, may be seen in equipment when low cost is a factor. Electrolytic capacitors which use a damp-paste type of electrolyte between the electrodes are used when high capacitance in a small package is needed.

TIMING CIRCUITS

When a resistor is connected in series with a capacitor and a DC voltage, a timing circuit is produced. A resistor and capacitor connected in series like this is called an RC, for resistance capacitance, circuit. The RC circuit works well as a timer because

it always behaves in the same way. In any RC circuit 5 × RC = t. That is, 5 times R in megohms, C in microfarads, equals the time in seconds for the capacitor to fully charge. The capacitor is said to be fully charged when electrons have stopped flowing in the charging circuit.

The product R × C is called a time constant because no matter what voltage is used to charge the capacitor, the time required to reach full charge does not change. Charging time in an RC circuit remains constant because at high voltages more electrons are needed to fully charge the capacitor, and at lower voltages fewer electrons are needed for a full charge.

In the timing circuits used in photo equipment, it's often necessary to change the time constant of an RC circuit in order to provide different intervals of operation. The most common way of altering an RC circuit's time constant is to change the value of the resistor in series with the capacitor. Variable resistors are often used in this application.

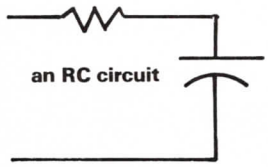


FIGURE 69

CAPACITORS IN AC CIRCUITS

When an alternating current power source is connected across a capacitor, it appears that an electric current passes through the capacitor. A capacitor appears to conduct AC because electrons are pushed onto and pulled from its plates as the AC voltage swings negative and positive.

TEST YOURSELF QUIZ #10

A capacitor is constructed of two CONDUCTORS separated by an INS.

When in use, a POTENTIAL DIFFERENCE exists between the plates of a capacitor.

R × C is called TIME CONSTANT.

5R × C is the time it takes for a capacitor to reach FULL CHARGE.

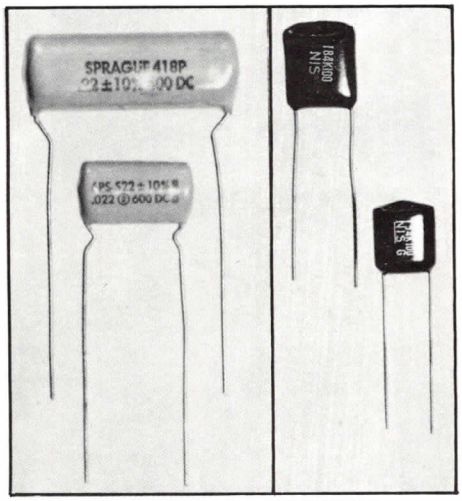
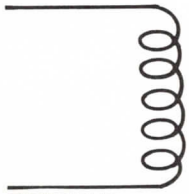


FIGURE 70 **FIGURE 71**

Commonly used capacitors.

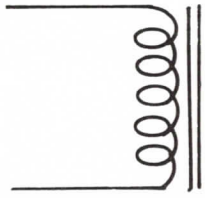
ELECTROMAGNETS

When an electric current passes through a conductor, a magnetic field occurs around the conductor. Stopping the electric current causes the magnetic field to disappear. Because the field around a conductor is caused by an electric current, it's called an electromagnetic field.



Schematic symbol for an electromagnet

FIGURE 72



Schematic symbol for an electromagnet with an iron core

FIGURE 73

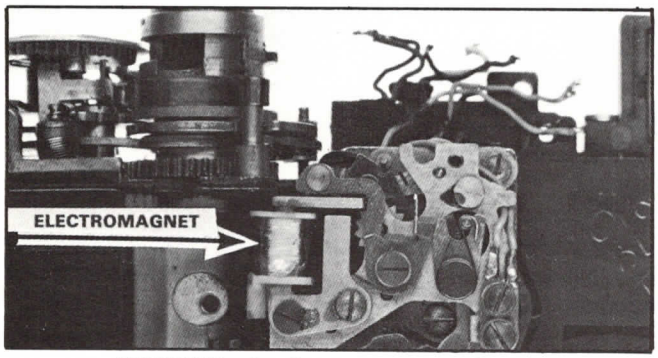


FIGURE 74 **An electromagnet used to time exposures in a Copal Square shutter.**

Schematic symbol for a fuse



FIGURE 75

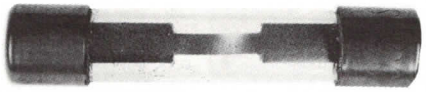


FIGURE 76 **A size 3AG fuse, the type often found in photo equipment.**

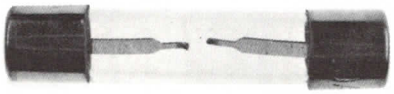


FIGURE 77 **A blown fuse is easy to spot.**

Coiling a current carrying conductor concentrates the magnetic field. A coil used to concentrate an electromagnetic field is called an electromagnet. Electromagnets are often wound around forms made of soft iron to further concentrate the magnetic field.

In future assignments you'll see electromagnets used to operate electrical contacts, trip shutters, time exposures and more.

FUSES

Although you'll probably never see a fuse in a camera or exposure meter, fuses are used in almost all AC operated equipment. The **fuse** acts as a safety valve for electrical circuits. The fuse is constructed so that its conductor melts, interrupting the circuit, if too much current tries to pass through the fuse. Because the conductor in a fuse melts when the fuse is overloaded, a burned out fuse cannot be re-used. It must be discarded and a new fuse installed.

A cousin to the fuse is the **circuit breaker.** The circuit breaker also interrupts the circuit if an overload occurs. Unlike the fuse the circuit breaker need not be replaced when it "blows." The circuit breaker can be reset.

INDICATOR LAMPS

The two most commonly used types of indicator lamps are the filament and the gas-filled type. A third type rapidly gaining popularity, the LED, is covered later in your course.



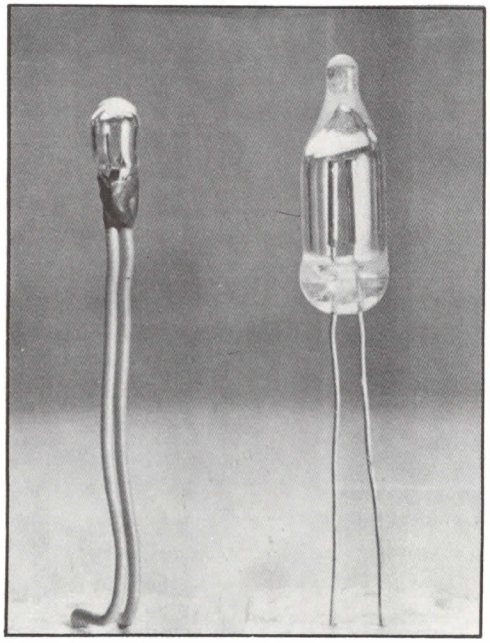
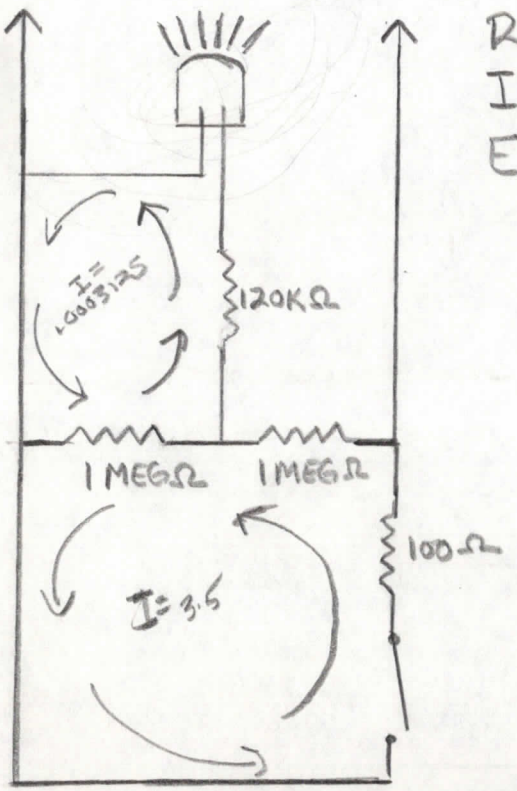


FIGURE 78

350 volts



$R_T = 99.9\,\Omega$
$I = 3.5$ WATTS
$E = 350$ VOLTS
} ACROSS LEADS

627
5456

FILAMENT LAMPS

A filament indicator lamp is a miniature version of the standard household bulb. A small metal filament in a vacuum or inert gas is heated by the flow of electric current. The heated filament gives off light. A variety of filament lamps are manufactured to work on many different voltages. Some lamps operate at less than one volt, while other lamps need over 100 volts to operate.

One other point is worth noting. A filament lamp will work at voltages other than the one which it was designed to. As the voltage across a filament lamp is decreased, the lamp dims and its light grows redder. If on the other hand the voltage is increased, the lamp glows more brightly and at some increased voltage the lamp burns out.

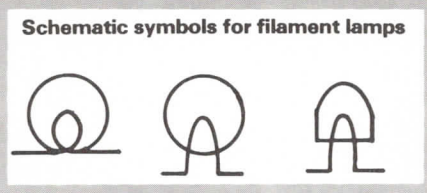


FIGURE 79

GAS—FILLED LAMPS

You'll see gas-filled indicator lamps used in a variety of photographic equipment. Gas-filled lamps are popular as indicators because they have a long life, operate at low current and produce little heat. On the minus side, gas-filled lamps don't put out as much light as a comparable size filament lamp, and the gas-filled lamp requires high voltages to operate.

Instead of depending upon a heated filament to produce light, the gas-filled indicator lamp gives off light due to the effect of a potential difference on the gas in the lamp. Unlike the filament-type lamp, a gas-filled lamp has a distinct turn-on voltage. Below its turn-on voltage, the lamp will not glow and conducts almost no current. When the lamp's turn-on voltage is reached, the lamp glows. Once glowing, the lamp is a very good conductor of electricity, so a resistor is placed in series with the lamp to limit the current. Without a series-limiting resistor, a gas-filled lamp would burn up in a very short time.

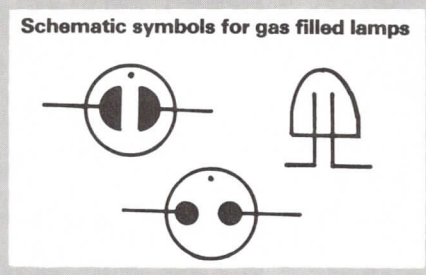


FIGURE 80

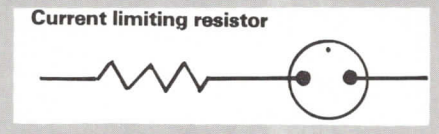


FIGURE 81

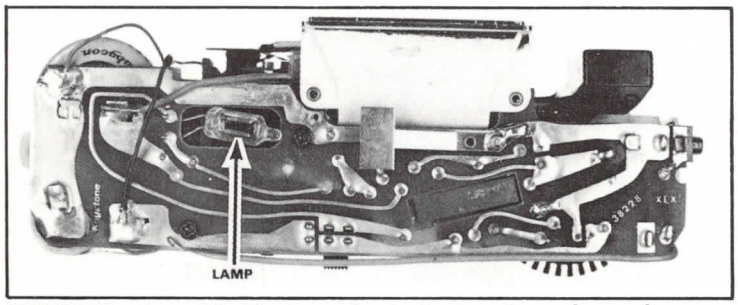


FIGURE 82 A gas filled lamp used to indicate a charged capacitor.

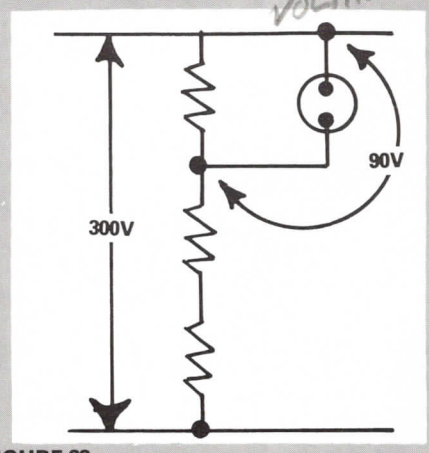


FIGURE 83

Due to the low current needed for their operation, it's practical to operate gas-filled lamps from voltage dividers. Selection of suitable resistors allows gas-filled lamps which turn on around 90 volts to be used in circuits operating at 300 or more volts.

Schematic symbol for a relay

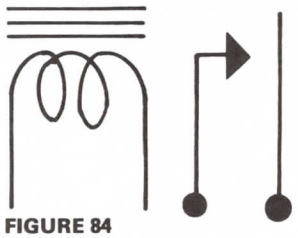


FIGURE 84

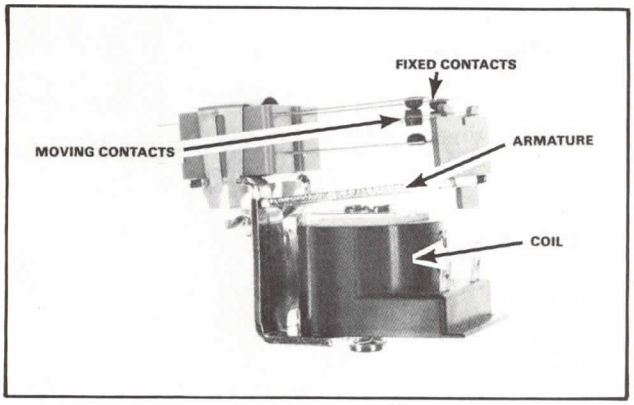


FIGURE 85 The parts of a relay.

THE RELAY

The electromagnet which we mentioned earlier may be found controlling switches in electrical circuits. When an electromagnet is combined with a switch a **relay** is what results. The relay used the electromagnetic force created by a coil of wire to attract an armature. The armature in turn operates a set of switch contacts. Relays are useful because a low power circuit may be used to power the coil while the relay contacts control a high power circuit.

SHIELDING

Every electric circuit is surrounded by invisible magnetic fields. In addition some circuits emit radio waves. Because the magnetic field or radio waves generated by one part of a circuit may interfere with another part of the circuit, many circuits employ **shielding.** Shielding prevents one circuit from interfering with another.

Schematic symbol for sheilding



FIGURE 86

A number of types of shielding are used in photographic electronics. Circuits are often shielded by placing them inside of metal foil containers. Wires may be shielded by surrounding them with a metal braid. But the most common form of shielding in photo-electronics is also the simplest. Wires are just twisted together. Because twisting of wires is used to prevent the current in one wire from interfering with the current in another wire, it's important for you to retwist any wires you unwrapped while completing a repair.

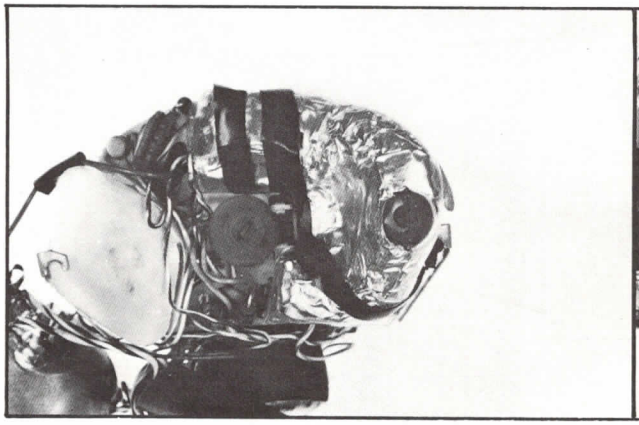


FIGURE 87 Metal foil used to provide shielding.

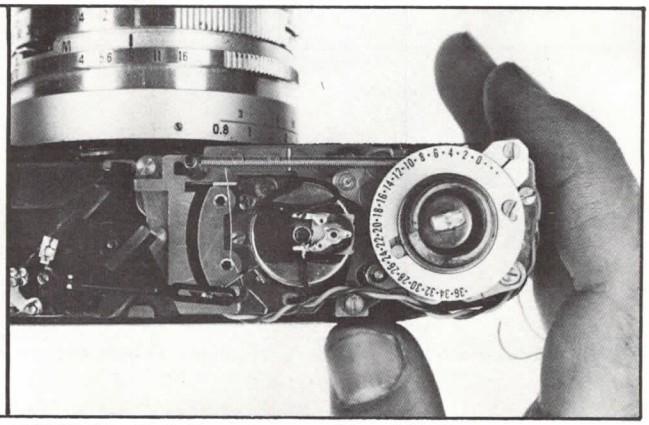
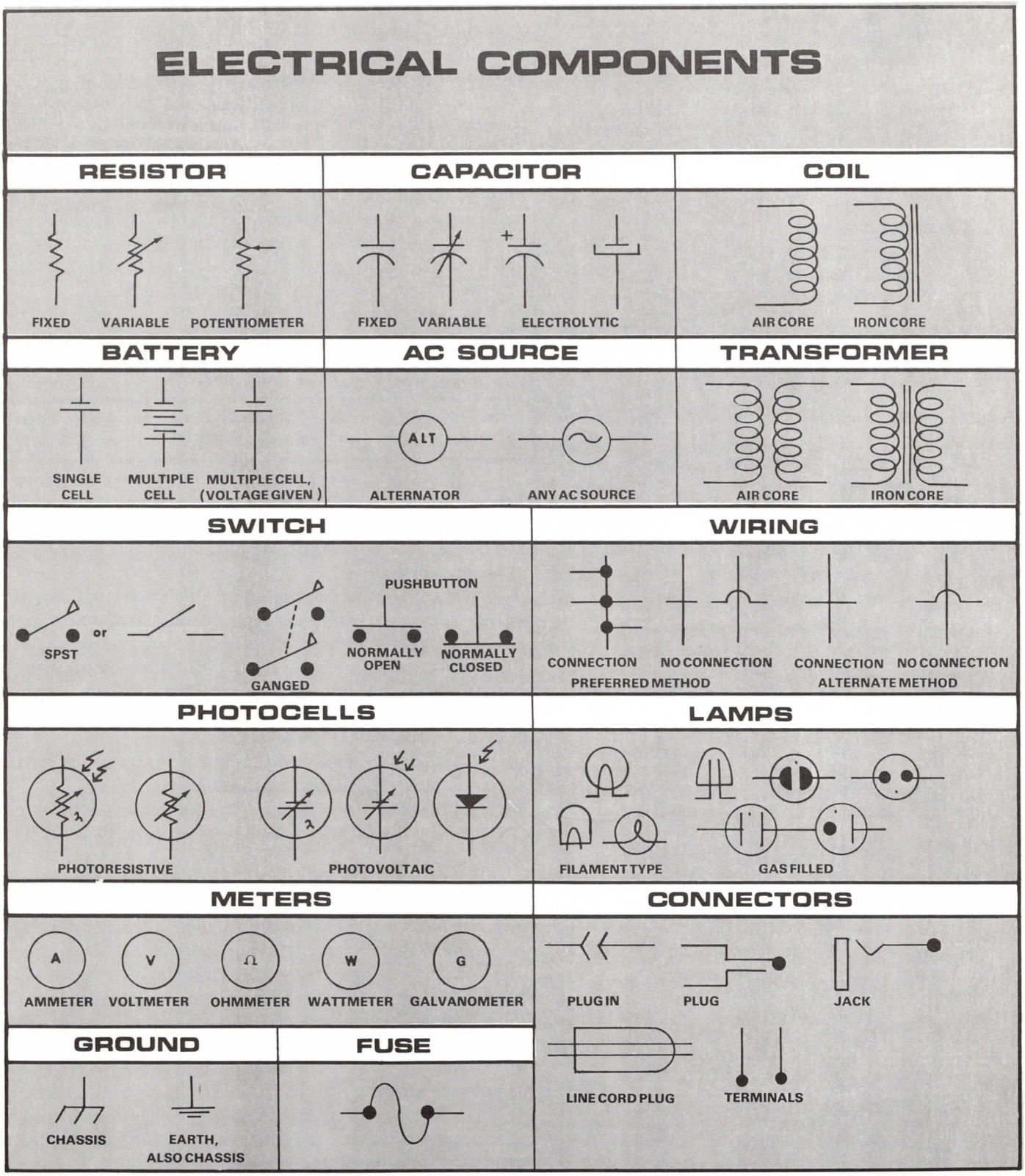


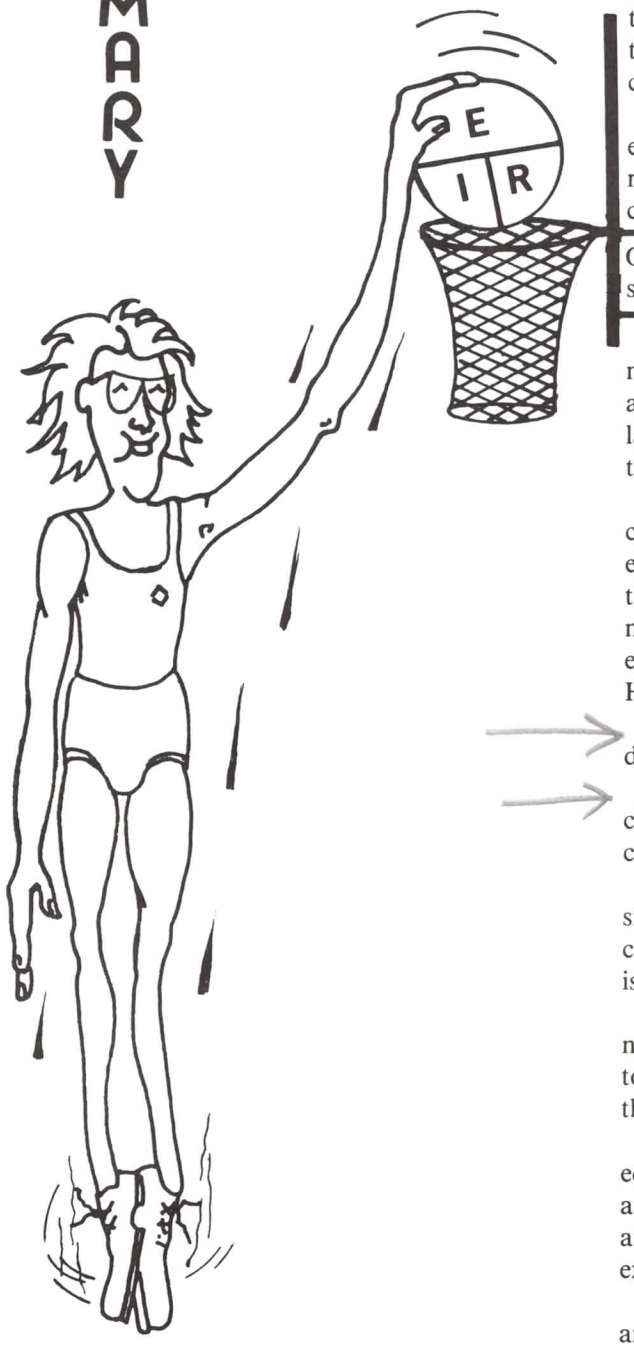
FIGURE 88 Twisting wires provides shielding.

NOTE SHIELD.

ELECTRICAL COMPONENTS



SUMMARY



Understanding electricity starts with understanding the fundamental building block of matter, the atom. It's one of the components of the atom, the electron, that is necessary for the electron flow which we call electricity.

Electron flow requires pressure on free electrons. The pressure applied to electrons is called electromotive force (EMF). EMF is measured in volts, but it's convenient to think of volts being the force moving electrons. A common source of EMF in the form of potential difference is the electrochemical cell. The cell causes electron flow by creating a surplus of electrons at one of its terminals and a deficiency at the other. Once electrons are moving, their flow can be measured. The flow of electrons is known as current. Current is measured in amperes or amps.

Flowing electrons are used to do work, and whenever electrons do work they encounter resistance. The amount of resistance encountered, the voltage applied and the current in a circuit are all related to each other. The relationship is known as Ohm's law. We've presented Ohm's law this way: Where E represents voltage, I current and R resistance.

Ohm's law is very useful, but two other laws are also needed in order to describe more than the simplest circuit. The additional laws are Kirchoff's voltage law and Kirchoff's current law. These laws are necessary because a circuit may contain more than one resistance.

Circuits containing more than one resistance may be series circuits or parallel circuits. In a series circuit, there is one path for electrons, so any electron entering the circuit must eventually pass through every resistance in the circuit. In a parallel circuit, there is more than one path for electrons. This means that an electron entering the circuit may pass through any one of the parallel paths. Here, then, are Kirchoff's laws.

Kirchoff's voltage law says that the sum of all voltage drops in a series circuit must equal the applied voltage.

Kirchoff's current law says that the current going into a circuit at the branch of a circuit must be equal to the current coming out.

In most circuits, a greater voltage than can be provided by a single cell is necessary. To produce a greater voltage, individual cells are connected in series to make a battery. A battery's voltage is the sum of the voltages of its series-connected cells.

Sometimes more current than a single cell can provide is needed. In these cases, the cells are connected in parallel, and the total current available is the sum of the maximum currents of all the cells. However, this battery's voltage remains that of one cell.

Although cells and batteries are often used to power photo equipment, alternating current powers many electrical devices. In an alternating current circuit, the voltage swings to both positive and negative. Ohm's law and Kirchoff's laws apply to AC circuits exactly the same way as they apply to DC circuits.

When batteries, resistors and other electrical components are connected to form a circuit, the diagram used to represent the circuit is called a schematic diagram. A schematic diagram uses symbols to represent the circuit's components.



ANSWERS

ANSWERS TO TEST-YOURSELF QUIZZES

QUIZ #1

1. The fundamental building block of all matter is the **atom.**
2. The **nucleus** of the atom is surrounded by orbiting **electrons.**
3. Atoms with **free electons** in their outer shells make good conductors.
4. Atoms with few free electrons are **insulators.**

QUIZ #2

1. Having more electrons at one end of a conductor than at the other creates a **potential difference.**
2. PD and EMF are both measured in **volts.**
3. Electron flow is measured in **amps.**
4. A circuit doing work **resists** the flow of electrons.
5. Chemical energy is converted to **electrical** energy in a battery.

QUIZ #3

1.



2. When working with Ohm's law, E is use to indicate volts, I indicates current and R indicates resistance.
3. V stands for **volts,** A for **amps** and Ω for **resistance.**
4. The problem is I = E/R. The solution will be in **amps.**
5. Using Ohm's law, R = E/I, we have 1½ volts/1 amp = **1½ ohms.**
6. Ohm's law gives E = IR, so ½ amp × 10 Ω = **5 volts.**
7. I = E/R, so 18 volts/36 Ω = **½ amp.**

QUIZ #4

1. The **resistance** in a circuit converts electric energy into other forms of energy.
2. Watts = E × I or **volts × amps.**
3. A milliamp is 1/1000 amp, so there are **2000 milliamps** in 2 amps.
4. Kilo means **multiply** by 1000.
5. 22MΩ is 22 Megohm or **22 million ohms.**

QUIZ #5

1. Battery
2. Open Switch
3. Ground (chassis)
4. Unconnected Wires
5. Resistor
6. Connected Wires

Ohm's Law Problems

7. Using Ohm's law I = E/R, so I = 1.5V/1.5Ω = **1 amp.**
8. Using Ohm's law R = E/I, so R = 10V/½A, R = 10V × 2/1, **R = 20Ω.**
9. Using Ohm's law, E = I × R, so E = ¼A × 100Ω, E = 100/4, **E = 25 V.**
10. I = E/R, I = 1 volt/4Ω, **I = ¼A.**
11. **Zero amps.** The switch is open.

QUIZ #6

1. There is only one electron path in a **series** circuit.
2. Kirchoff's voltage law says that sum of the **voltage drops** in a series circuit equals the **voltage** applied.
3. The battery provides **8 volts.**
4. Kirchoff's current law says that the current into a circuit must equal the current out. So, **2 amps.**
5. A battery will see the **sum** of the resistances in a series circuit.
6. Each of the branch currents must come from the battery, so total current is 1a + 3a + 4½a = **8½ amps.**

QUIZ #7

1. A mercury cell is a **1.35 V.** cell. Three mercury cells in series will provide **4.05 V.**
2. Three mercury cells in parallel provide **1.35 V.**
3. SW_1 is open, SW_2 is closed.
4. **6 cells** will provide 9v.
5. $R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2}$, $R_{eq} = \frac{18 \times 18}{18 + 18}$, $R_{eq} = \frac{324}{36}$, $R_{eq} = 9\,\Omega$ or $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$, $\frac{1}{R_{eq}} = \frac{1}{18} + \frac{1}{18}$, $\frac{1}{R_{eq}} = \frac{2}{18}$, $\frac{1}{R_{eq}} = \frac{1}{9}$, $R_{eq} = 9\Omega$
6. Total current is ½ amp, so since the voltage is 9 volts, total resistance $= \frac{9 \text{ volts}}{\frac{1}{2} \text{ amps}}$ or 18Ω. The known resistor is 9Ω, so the value of R_{eq} is 9 Ω because in a series circuit the resistances are added to obtain total resistance.
7. I = E/R, so I = 4 volts/12Ω = **1/3** AMP with SW_1 open. With SW_1 closed, the equivalent resistance R_{eq} is $1/R_{eq} = 1/12\Omega + 1/24\Omega$, $1/R_{eq} = 2/24 + 1/24$, $1/R_{eq} = 3/24$, $1/R_{eq} = 1/8$, $R_{eq} = 8\Omega$.
8. When SW_1 is open, equivalent resistance is $R_{eq} = \frac{R_1 \times R_2}{R_1 + R_2}$, $R_{eq} = \frac{36\,\Omega \times 18\Omega}{36\Omega + 18\Omega}$, $R_{eq} = \frac{648}{54}$, $R_{eq} = 12\Omega$.
9. When SW_1 is closed, equivalent resistance is $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3$ $1/R_{eq} = 1/36\,\Omega + 1/18\,\Omega + 1/12\Omega$, $1/R_{eq} = 1/36 + 2/18 + 3/36$, $1/R_{eq} = 6/36$, $1/R_{eq} = 1/6$, so R_{eq} is 6Ω.

↑ 2/36

QUIZ #8

1. Direct current is seldom transmitted over long distances because **alternating current** is transmitted much more efficiently.
2. In an alternating-current circuit, an individual electron moves **back** and **forth.**
3. **Positive peak**

   zero volts

   negative peak
4. The number of cycles occurring in one second is known as **frequency** which is expressed in **hertz.**
5. Using Ohm's law, I = E/R, so I = 10v/10Ω = **1 A.**

6. Watts = I × R, so in this circuit Watts = 110 volts × ½ amp. **55 watts** of power are being used.
7. Kirchoff's voltage law says that the sum of the voltage drops equal the supply voltage, so 50v + 30v + 20v = **100 volts.**

QUIZ #9

1. **Metal film** resistors are quite heat sensitive.
2. **1000** Ω with no more than 10% error.
3. **21000** Ω (±20%)
4. **520000** Ω (±20%)
5. **44** Ω (±20%)
6. **90** Ω (±20%)
7. **7.5** Ω (±20%)

QUIZ #10

1. A capacitor is two **conductors** separated by an **insulator.**
2. A capacitor has a **potential difference** between its plates when it's in use.
3. RC is a **time constant.**
4. 5RC is the period of time it takes for a capacitor to reach **full charge.**